Residual Wood Fiber Regional Needs Assessment, Market & Investment Opportunities Analysis

Completed for:

U.S. Endowment for Forestry and Communities

Completed by:

THE BECK GROUP

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CHAPTER 1 – EXECUTIVE SUMMARY

1.1 INTRODUCTION

This report provides an assessment of the current state of mill residuals (MR) and small diameter roundwood (SDR or pulpwood) utilization across the United States. Included is a regional analysis that quantifies the level of utilization (Chapter 2); a review of the factors affecting why certain regions, technologies, and markets perform well (Chapter 3); and a quantification of the fundamental economic structure underlying a variety of utilization pathways (Chapter 4). Together, these analyses help identify where underutilized wood fiber exists, which technologies are most aligned with regional conditions, and where investment and policy interventions are most likely to support durable, market-based outcomes. The U.S. Endowment for Forestry & Communities (USE) retained The Beck Group (BECK), a Portland, OR-based forest products planning and consulting firm, to complete the study. BECK appreciates the opportunity to work on this important topic.

1.2 REGIONAL NEEDS ASSESSMENT

Supply/Demand Balance—Chapter 2 of this study provides a national and regional assessment of opportunities to expand utilization of SDR and MR within the U.S. forest products sector. The assessment uses a regional approach, in which key factors such as supply, demand, forest growth and mortality, industrial infrastructure, fiber ownership, and economic conditions were quantified across nine forest products-producing regions. A key component of the regional assessment was the calculation of the estimated annual wood fiber supply-and-demand balance as shown in **Table 1.1**.

> ***Key Insight: Under current operating conditions, the U.S. forest harvest totals 270 million BDT/Year and demand is estimated at 213 million BDT/year, resulting in a net surplus of approximately 56 million bone dry tons (BDT) per year. The surplus is concentrated in pulpwood/small diameter roundwood (20.5 MM), logging slash (20.2 MM), and mill residuals (15.4 MM).***

Table 1.1 – U.S. Wood Fiber Supply (or Deficit) by Region & Material Type (BDT[1]/Year)

Region	Sawtimber	Pulpwood	Logging Slash	Mill Residuals	Total
Appalachian	(10,000)	3,215,000	1,984,000	5,911,000	11,100,000
Great Lakes Midwest	3,000	4,233,500	901,000	54,500	5,192,000
Inland West	(6,000)	1,101,000	1,688,000	2,213,000	4,996,000
Northeast	21,000	7,748,000	991,000	(112,000)	8,648,000
Pacific Northwest	(12,000)	118,000	3,426,000	2,853,000	6,385,000
South - Central Zone	8,000	(218,000)	3,529,000	1,338,000	4,657,000
South - East Zone	(10,000)	4,204,000	4,498,000	1,841,000	10,532,000
South - Western Zone	(9,000)	54,000	3,188,000	1,379,000	4,612,000
Southwest	0	144,000	81,000	(6,000)	219,000
Total	**(15,000)**	**20,599,500**	**20,286,000**	**15,471,500**	**56,341,000**

[1] *Bone Dry Tons (BDT*) are a unit of weight used in the forest products industry that represent one ton (2,000 pounds) of wood with all moisture removed. A BDT measures the amount of dry wood fiber only, regardless of how wet the wood was when it was harvested or delivered. Because wood fiber always contains some moisture, a BDT is a theoretical unit only and is calculated on representative samples of the fiber being analyzed. It is used in the forest products industry and as the standard unit of measurement because it can be consistently applied across different wood fiber types, species, and moisture conditions.

Implications of Supply/Demand Balance Findings—Given the finding of significant SDR and MR surpluses, a key concept identified from this study is that underutilization is a result of *structural alignment*, which for the purposes of this study is defined as the degree to which wood fiber characteristics (species, size, shape, moisture, quality, etc.), industrial scale, market demand, timberland ownership, and operating conditions are aligned to support durable, market-based utilization.

For example, markets capable of supporting broad, durable utilization are those that operate at large scales and convert low-value roundwood and mill residuals into higher-value products, increasing the value of the raw material relative to its delivered cost. In such cases structural alignment exists. However, many existing pathways for low-grade fiber generate insufficient product value to support widespread and sustained utilization. Among those types of pathways structural alignment is low. It should be noted that while thin margin markets/utilization pathways may play a role certain locations, they are unlikely on their own to resolve persistent structural surpluses at regional or national scales.

Also, the analysis identified that three different types of constraints dominate utilization outcomes in different parts of the country. In the U.S. South, for example, a region with extensive private ownership and established industrial infrastructure, *economic constraints* are most often binding, with utilization limited by market prices and product value rather than physical availability of fiber. *Physical constraints* occur in dry-forest regions where small diameter roundwood is abundant but occurs in scattered stands on steep terrain, with limited road access and high moisture variability, making a large share of the biological supply physically difficult or costly to recover. Finally, *institutional constraints* occur in areas dominated by Federal land ownership where long planning horizons and supply uncertainty impact the pace and predictability of material flow, even where resource availability and potential markets exist. Utilization outcomes are shaped less by biological supply and more by contracting mechanisms, policy frameworks, and the pace and scale of implementation on public lands. Regions such as the Pacific Northwest occupy an intermediate position, where strong markets and infrastructure coexist with institutional and cost constraints that vary by subregion and ownership mix.

Overall, the analysis demonstrates that regional utilization outcomes are shaped primarily by structural factors rather than fiber availability alone. Regions with extensive, high-throughput, and diversified infrastructure, which is particularly the case in the U.S. South, are better positioned to absorb low-grade material, yet still exhibit significant surpluses where market demand does not fully extend to mill residuals or logging slash. Other regions, such as the Inland West and Southwest, face a different form of structural misalignment in which abundant restoration-driven material coincides with limited industrial scale and heavy reliance on public lands and policy-dependent investment.

Taken together, the findings demonstrate that expanding utilization of small diameter roundwood and mill residuals is not constrained by forest growth or long-term sustainability, but by the alignment of utilization pathways with regional structural conditions. Durable solutions will require region-specific strategies that address market development, pathway compatibility, ownership constraints, and operating economics, rather than uniform capacity expansion. The scale of additional sustainable harvest implied by growth-to-drain parity far exceeds current surplus volumes, indicating that future utilization outcomes will be determined primarily by market alignment rather than fiber availability. These insights provide the foundation for the composite regional readiness assessment and the identification of targeted, high-leverage investment opportunities.

Achieving improved structural alignment will require coordinated strategies that address multiple system constraints simultaneously. For example, key recommended actions include targeted market development for products capable of absorbing large volumes of low-value fiber; pathway selection and technology deployment that are explicitly matched to regional fiber characteristics and scale; policy and ownership mechanisms that convert biologically available growth into reliably accessible supply, particularly on public lands; and investments that improve operating economics by reducing delivered cost, improving logistics, and leveraging existing infrastructure. Together, these strategies shift the focus from expanding harvest alone to aligning markets, pathways, and institutions with the material that forests actually produce.

Key Insight: The central challenge is not how much wood the forest can produce, but how effectively markets, technologies, and institutions are aligned to use it.

Economics Matter—End product prices and raw material input costs are the critical variables that determine whether surplus fiber is actually utilized. While this analysis demonstrates that substantial volumes of small diameter roundwood and residuals are physically available, material is utilized only when delivered costs can be supported by market prices for end products. Many of the fiber surpluses identified in this study reflect material that is physically available but cannot be economically utilized under current market conditions, because most existing utilization technologies do not generate sufficient value from the products produced to cover the costs of harvest, handling, transportation, and processing. As a result, persistent surpluses should be interpreted as indicators of economic and market misalignment rather than as evidence of untapped, low-cost supply.

Key Insight: Fiber availability does not equate to economic availability; wood is utilized only when market prices support delivered costs, or when policy interventions create conditions supporting utilization.

Fiber Availability is Not a Constraint—Beyond the current fiber supply and demand balance, the analysis revealed that annual forest growth substantially exceeds combined annual harvest and natural mortality across most U.S. regions. If harvests were to rise to levels making annual growth equal to the combination of harvest and natural mortality (i.e., a growth-to-drain ratio of approximately 1:1), U.S. forests could theoretically support additional harvest of about 200 million BDT of wood fiber per year nationally. In other words, from a purely biological perspective, U.S. forests could support harvests almost approaching double the current rate.

The largest gaps between effective growth and current harvest occur in the three Southern regions (South, Central, and Western zones), Appalachia, and the Northeast. Regions such as the Pacific Northwest and Inland West are closer to balance. This finding highlights the need for region-specific utilization strategies rather than uniform national solutions.

This theoretical harvest gap is about four times larger than the current modeled fiber surplus. This finding underscores that today's underutilization is not driven by biological limits on supply, but by market structure, utilization pathways, and structural alignment. In other words, current markets and technologies cannot support increased harvesting. Note that harvesting an additional 200 million BDT/year is not a recommendation or forecast; rather, it is the ceiling of additional volume that could be sustainably harvested. In practice, realizing even a small fraction of this currently unutilized annual growth depends on developing utilization pathways that return sufficient value to cover delivered costs and overcome institutional barriers.

Key Insight: Current fiber surpluses represent only a small fraction of the wood that could be sustainably harvested if utilization pathways and markets were aligned with forest growth.

Comments About Methodology—Please note that in the modeling used to generate the supply/demand balance for sawtimber supply and demand were intentionally constrained to be approximately equal, reflecting the real-world behavior that sawtimber is generally harvested only when established commercial markets exist. As a result, sawtimber markets are essentially balanced at both the national and regional levels. This pattern indicates that underutilization is not driven by excess sawlog production, but by limited market demand and *pathway compatibility* (i.e., mismatches between material characteristics and the technical, economic, and scale requirements of available utilization pathways) for lower-value co-products generated through commercial harvesting, primary milling, and forest restoration activities.

Another important caveat to the preceding table is that mill residuals are also consumed internally at many wood products facilities for wood fiber drying and other process heat needs. Because these internal transfers are typically not metered or recorded as sales transactions, internal boiler consumption (estimated on the order of 10 million BDT/year nationally) is not fully reflected in the modeled demand total. This means that the surplus of mill residuals likely overstates the volume available to external markets.

1.3 KEY MARKET & INVESTMENT OPPORTUNITY ANALYSIS

The second phase of the analysis (Chapter 3) involved translating the regional findings from the Needs Assessment into a structured view of where real market and investment opportunities exist for utilizing small diameter roundwood and mill residuals.

Rather than treating utilization options as a long list of technologies, this report classifies utilization pathways into three groups, each playing a distinct role in the broader wood fiber system:

- **System Anchors** absorb large volumes of material at scale and play a stabilizing role in regional markets.
- **Volume Absorbers** can meaningfully reduce surpluses under the right conditions and logistical conditions, but typically lack the scale or durability to anchor markets on their own.
- **Policy-Dependent Pathways** can operate at scale, but rely on policy support or incentives to be economically viable.

Key Insight: Not all utilization pathways contribute meaningfully to reducing regional fiber surpluses.

The analysis shows that utilization outcomes are shaped less by a technology's sophistication or novelty and more by its market role. For example, large structural markets such as lumber and panels, pulp, and certain energy pathways continue to function as the primary system anchors of the wood fiber system. These markets largely determine whether lower-value co-products are absorbed or left stranded.

By contrast, many newer or smaller-scale pathways perform valuable but supporting roles: improving recovery, adding local value, or addressing specific material streams. These pathways are often important complements to anchor markets, but they are not substitutes for them.

Feedstock fit and required operating scale are binding constraints on utilization success. Mill residuals are generally the most economically accessible feedstock due to their concentration, consistency, and low handling costs. Small diameter roundwood can support viable markets where scale, logistics, and high product values align, but this feedstock often struggles to compete with established supply chains unless paired with high-volume or policy-dependent pathways. Logging slash remains the most difficult material to utilize due to high recovery costs and limited compatible markets.

This distinction reinforces a key conclusion from Chapter 2: Fiber availability alone does not determine utilization outcomes. Material is only used when product markets can support delivered costs at the scale required.

Key Insight: Pathways that tolerate variable feedstocks and operate at appropriate scale are consistently more viable than those requiring narrow specifications or large, centralized facilities.

Utilization pathways are differentiated by their reliance on policy support and the durability of private investment they are likely to attract. Some pathways, particularly those tied to restoration, energy, or early-stage bioproducts, play important roles but remain heavily policy-dependent. Others operate largely on market fundamentals and can attract long-term private capital once initial alignment conditions are met. This distinction is especially important for investment strategy. Policy-dependent pathways can be effective tools for addressing near-term forest health and wildfire objectives, but durable utilization at scale ultimately depends on pathways that can survive market cycles without continuous subsidy.

Key Insight: Policy dependence changes the investment logic, not the value of the pathway. Some wood utilization pathways depend on policy support because they deliver public benefits not fully reflected in market prices, and those pathways require different investment expectations than market-driven industries.

The market investment and opportunity analysis suggests that effective strategies for expanding utilization should:

- Prioritize pathways capable of absorbing material at scale, even if they are technologically mature rather than differentiated by innovation.
- Use niche and emerging pathways strategically as complements (rather than replacements) for anchor markets.
- Match pathway selection to regional feedstock characteristics, ownership context, and infrastructure scale.
- Distinguish clearly between policy-dependent demonstrations and market-driven investment opportunities.
- Focus on pathways with sufficient market size and durability to justify private capital deployment.

1.4 ECONOMIC CAPACITY OF WOOD UTILIZATION PATHWAYS

As already described, across much of the United States, small diameter roundwood and mill residuals are increasingly abundant but unevenly utilized. In many regions forest growth exceeds removals, mortality rates are rising, and treatment-driven material (particularly from fuels reduction and forest health activities) continues to lack consistent, economically viable outlets. Addressing this imbalance requires not only identifying potential utilization pathways, but understanding how those pathways function economically within broader wood fiber systems.

Accordingly, Chapter 4 of this report evaluated a wide range of wood utilization pathways. Rather than focusing on site-specific feasibility or individual project economics, the analysis examines the economic capacity of different pathways to support delivered wood fiber costs, expressed through a Return-to-Log/Return-to-Fiber (RTL/RTF) metric. RTL/RTF represents the maximum delivered value that a pathway could return to wood fiber after accounting for non-feedstock conversion costs under representative operating assumptions. In other words, RTL/RTF values are the break-even delivered raw material cost. **Table 1.2** provides a high-level summary of the RTL/RTF results. See Chapter 4 for additional details and quantification of RTL/RTF values. Table 4.2 in Chapter 4 provides a consolidated view of the economic capacity, scale, and policy dependence of major utilization pathways and is intended to serve as a reference point for investment and policy screening. It is worth reviewing closely.

Table 1.2 – Indicative Economic Capacity & Scale by Pathway Type

Pathway Type	Indicative RTL/RTF Range	Typical Facility Scale	Policy Dependence
System Anchors	Moderate ($80–$200/BDT)	Very Large	None
Volume Absorbers	Variable (Low–High)	Small to Medium	Low
Policy-Dependent	Near zero without policy	Large	High

1.4.1 Key Findings

- **No single utilization pathway can resolve small diameter roundwood and mill residual surpluses on its own**. The analysis confirms that effective utilization depends on a portfolio of pathways, each playing a distinct role. Some pathways provide scale and stability; others offer flexibility and targeted outlets, and still others depend fundamentally on policy support. Efforts to address utilization challenges that focus on a single technology or market are unlikely to succeed at regional scale.
- **System anchor industries remain the foundation of wood utilization systems.** Commodity lumber, plywood, oriented strand board (OSB), and pulp-and-paper manufacturing continue to function as system anchors. While their RTL/RTF values are generally moderate relative to some higher-value niche pathways, their large facility scales, mature global markets, and ability to absorb large volumes of wood fiber result

in very high total annual fiber value per facility. These industries establish durable market signals, stabilize supply chains, and underpin the economic viability of most forest products regions.

- **Volume absorber pathways play an important but complementary role**. Composite panels, wood-based insulation products, pellets, and thermal energy applications can utilize meaningful volumes of small diameter material and mill residuals, often with greater tolerance for lower-quality fiber. Some of these pathways can return relatively high value to fiber under favorable conditions. However, they typically operate at smaller scale, rely on narrower feedstock specifications, or serve markets with limited depth. As a result, they are best understood as complements to system anchors—enhancing system flexibility and utilization efficiency—rather than as replacements.
- **Scale and context strongly influence economic outcomes**. Across nearly all pathways, facility scale is a key determinant of economic performance and system impact. Larger facilities tend to achieve lower unit conversion costs and higher RTL/RTF values, particularly in energy applications, but also require larger and more consistent feedstock supply areas as well as higher capital investment. Pathways that appear attractive on a per-ton basis may be impractical in regions lacking sufficient feedstock concentration, infrastructure, or market access.
- **Policy-dependent pathways require explicit and durable policy rationale**. Biomass-based power generation and biomass-to-liquid fuel pathways do not support positive delivered feedstock values based on market fundamentals alone. Where these pathways show positive RTL/RTF outcomes, those outcomes are driven by policy incentives, avoided-cost structures, or regulatory mandates. Because these facilities often operate on a very large scale, the implied annual value of policy support can be substantial. Deployment of these pathways should therefore be guided by clear public objectives—such as emissions reduction, energy reliability, or wildfire risk mitigation—rather than expectations of market-driven competitiveness.

Key Insights:

No single utilization pathway can economically absorb small diameter roundwood and mill residual surpluses at scale.

System anchor industries provide the majority of total fiber utilization and establish durable market signals, despite moderate per-ton returns.

Volume absorber pathways improve system flexibility and utilization efficiency but operate at smaller scales and narrower market depths.

Economic outcomes are highly sensitive to facility scale, feedstock characteristics, and regional context.

1.4.2 Implications for Strategy & Decisionmaking

The results of this analysis underscore that improving utilization of small diameter roundwood and mill residuals is not primarily a technology-selection problem. Instead, it is a system design challenge that requires aligning markets, scale, feedstock characteristics, and policy objectives.

Successful strategies will:

- Maintain and strengthen system anchor industries that provide scale, stability, and durable market signals.
- Support selective deployment of volume absorber pathways to address specific feedstock gaps, regional constraints, or resilience objectives.
- Apply policy support judiciously to enable pathways that deliver public benefits but are not supported by market economics alone.

RTL/RTF analysis provides a transparent and consistent framework for understanding these tradeoffs. By focusing on economic capacity rather than project-specific feasibility, this study helps clarify why utilization challenges persist, why no single solution dominates, and how a diversified portfolio of pathways can improve long-term wood fiber utilization outcomes.

> ***Key Insight: Taken together, the RTL results underscore that utilization challenges persist not because of a lack of available fiber, but because only a limited subset of pathways can absorb material at scale while supporting delivered costs.***

1.5 HOW TO USE THIS REPORT

This report is intended as a tool to support investment, policy development, and further due diligence related to the utilization of small diameter roundwood and mill residuals. It is not a facility siting study, procurement plan, or project-level feasibility analysis, and should not be interpreted as guaranteeing feedstock availability or economic performance for any specific project or location. Advancing any specific project will require additional, location-specific analysis, including detailed procurement modeling, capital and operating cost estimation, regulatory and permitting review, and market validation.

This analysis is not intended to be a fully comprehensive inventory of all wood-consuming facilities or transactions. It is designed to characterize system-level patterns in fiber availability, utilization, and economic alignment at regional and national scales. Regional-level inventories and local datasets might identify additional small or specialized facilities that are outside the scope of this assessment.

While results are presented primarily in tabular form to support quantitative comparison, the underlying data are well suited for spatial visualization and mapping in future work.

Results presented in this report reflect current operating conditions including prevailing market demand, mill utilization rates, and recent harvest behavior. They are intended to highlight structural patterns rather than predict short-term market fluctuations. Quantitative results are expressed at regional and national scales to support comparative assessment and strategic decisionmaking.

CHAPTER 2 – REGIONAL NEEDS ASSESSMENT

2.1 CHAPTER OVERVIEW

This chapter provides a quantitative and qualitative assessment of the condition and performance of the forest products sector across U.S. regions, with a focus on the utilization of small diameter roundwood (referred to as either SDR or pulpwood) and mill residuals (MR). More specifically, it seeks to identify the structural drivers of underutilization in the forest products sector. Rather than treating fiber surplus as a simple supply problem, the analysis emphasizes how industrial scale, ownership patterns, market access, and utilization pathways interact to determine whether available material can be economically used. Better understanding the interaction of these factors is essential for identifying where investment and policy interventions are most likely to be effective.

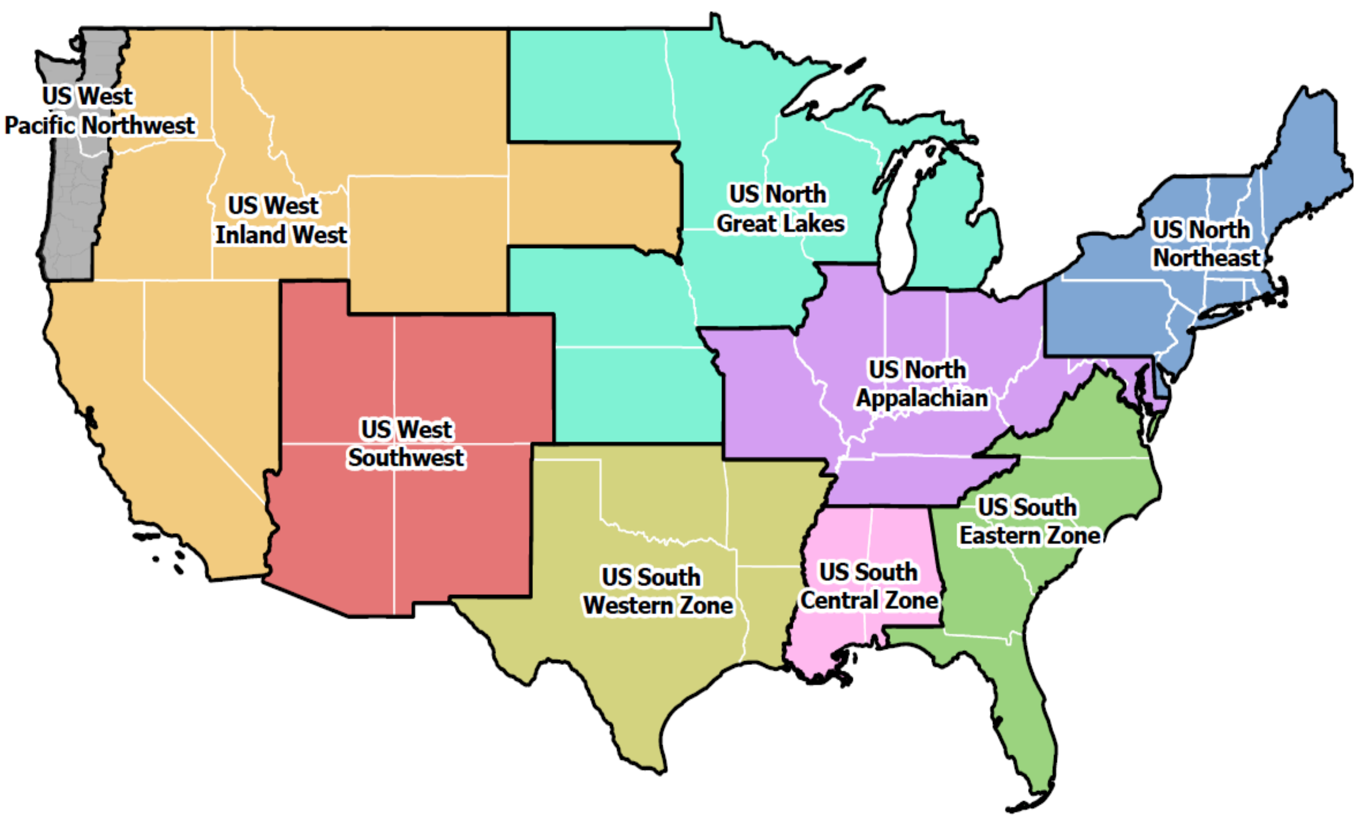
The analysis evaluates regional resource balances, existing industrial infrastructure, economic conditions, and forest characteristics (ownership, inventory, growth rates, etc.) to identify where underutilized materials are most prevalent and where structural, policy, or market barriers constrain their use.

Through indicators such as utilization efficiency, diversification, investment leverage, and timberland ownership, this assessment characterizes each region's relative readiness to expand SDR and MR utilization and sets the stage for the investment opportunity analysis that follows.

2.2 REGION DELINEATION

To assure consistent regional comparison across diverse forest and industry conditions, BECK divided the continental United States into nine forest products regions for this analysis as shown in **Figure 2.1**. The nine regions consist of: Appalachian, Great Lakes/(Midwest), Inland West, Northeast, Pacific Northwest, South/Central Zone, South/East Zone, South/Western Zone, and Southwest.

Figure 2.1 – Nine Forest Products Regions in the United States



These regions were grouped as shown because they share broadly similar forest types, ownership patterns, industrial structures, and market linkages. The regions also align with common industry reporting geographies, which helps ensure results are interpretable to practitioners. In other words, the boundaries align with ecological characteristics, industry infrastructure, and economic activity, which reflect the ways timber and wood fiber are commonly grown, harvested, and traded.

Each region includes a mix of forest ownership classes including Federal, State, local, and private. The wood fiber harvested in each region each year supports a network of forest products utilization infrastructure such as sawmills, panel plants, pulp-and-paper mills, energy facilities, and other forest-based industries. While state-level data were used in developing the inputs (e.g., Forest Inventory and Analysis [FIA] data, U.S. Bureau of Economic Analysis datasets, and mill directories), aggregating results to the regional scale smooths out local fluctuations and provides a national perspective on relative utilization and opportunity among regions.

These regions provide an analytical framework for assessing fiber availability, industrial capacity, and investment opportunity. The remainder of this chapter uses this same regional structure to compare fiber supply and demand, economic performance, and ownership context across the country.

2.3 ANNUAL FIBER SUPPLY & DEMAND BALANCE

A key component of the regional needs assessment is the comparison of annual fiber supply and annual demand for sawtimber, pulpwood, logging slash, and mill residuals across the nine U.S. regions. This supply-and-demand balance analysis quantifies the annual availability of these feedstocks relative to current industrial consumption, providing a measure of where excess material exists and where deficits may constrain market growth.

The analysis uses data from multiple sources, with supply estimates derived primarily from the U.S. Forest Service Forest Inventory and Analysis (FIA) program. For each region, FIA data were used to estimate average annual harvest levels based on recent years of reporting. These harvest volumes represent trees of all sizes, from larger sawtimber to smaller-diameter material. It represents total removals from commercial harvesting activities under current management conditions. Demand estimates were derived from FORISK's mill database.

For the purposes of this supply-and-demand model:

- Mill demand was adjusted from nameplate (full capacity) levels to estimated actual operating output, providing a more realistic representation of current demand.
- It was assumed that sawlog supply and demand are approximately in balance. This reflects the real-world behavior that sawtimber-sized trees are typically harvested only when a known commercial market exists. Under this assumption, sawtimber harvest represents the economic driver of forest management operations, while pulpwood, logging slash, and mill residuals are treated as co-products of that activity. In other words, this approach allows the analysis to isolate the true structural surplus in lower-value fiber streams, rather than attributing imbalance to overharvesting of sawlogs. Note that in practice, small, immaterial differences remain.
- The remaining fiber balance (after accounting for sawlog consumption) was therefore interpreted as the volume of small diameter roundwood, mill residuals, and logging slash that remains potentially available for new or expanded utilization.

The fiber balance for each region is calculated as:

Annual Fiber Balance = Total Annual Supply – Total Annual Demand

Positive balances indicate surplus material, representing feedstocks potentially available for new utilization or investment. Negative balances indicate regions already fully utilizing SDR, mill residuals, and/or logging slash. All results are expressed in bone dry tons per year (BDT/year) to enable direct comparison across regions. Supporting indicators such as annual growth, harvest, and mortality provide additional context. Together, these data illustrate the fiber dynamics of each region, specifically whether biomass is accumulating on the landscape (indicating underutilization and potential forest health concerns) or being efficiently converted into manufactured products and energy.

This analysis provides the quantitative foundation for the remainder of this chapter, thereby setting the stage for evaluating each region's industrial infrastructure, ownership patterns, and investment readiness. **Table 2.1** shows the results.

Table 2.1 – Estimated Wood Fiber Supply & Demand Balance in the United States by Region & Fiber Type (Bone Dry Tons per Year)

Supply					
Region	**Sawtimber**	**Pulpwood**	**Logging Slash**	**Mill Residuals**	**Total Supply**
Appalachian	7,133,000	6,669,000	2,001,000	6,877,000	22,680,000
Great Lakes/Midwest	4,462,000	10,386,000	989,000	2,462,000	18,299,000
Inland West	9,182,000	2,881,000	2,046,000	5,137,000	19,246,000
Northeast	5,460,000	12,107,000	1,177,000	2,781,000	21,525,000
Pacific Northwest	18,089,000	2,279,000	3,551,000	6,765,000	30,684,000
South/Central Zone	18,686,000	14,485,000	3,671,000	7,009,000	43,851,000
South/East Zone	23,519,000	37,713,000	4,807,000	10,127,000	76,165,000
South/Western Zone	16,200,000	9,941,000	3,262,000	6,636,000	36,039,000
Southwest	489,000	170,000	107,000	262,000	1,028,000
Total	**103,220,000**	**96,631,000**	**21,611,000**	**48,056,000**	**269,517,000**
Demand					
Region	**Sawtimber**	**Pulpwood**	**Logging Slash**	**Mill Residuals**	**Total Demand**
Appalachian	7,143,000	3,454,000	17,000	966,000	11,580,000
Great Lakes/Midwest	4,459,000	6,153,000	88,000	2,408,000	13,108,000
Inland West	9,188,000	1,780,000	358,000	2,924,000	14,250,000
Northeast	5,439,000	4,359,000	186,000	2,893,000	12,877,000
Pacific Northwest	18,101,000	2,161,000	125,000	3,912,000	24,299,000
South/Central Zone	18,678,000	14,703,000	142,000	5,671,000	39,194,000
South/East Zone	23,529,000	33,509,000	309,000	8,286,000	65,633,000
South/Western Zone	16,209,000	9,887,000	74,000	5,257,000	31,427,000
Southwest	489,000	26,000	26,000	268,000	809,000
Total	**103,235,000**	**76,032,000**	**1,325,000**	**32,585,000**	**213,177,000**
Balance					
Region	**Sawtimber**	**Pulpwood**	**Logging Slash**	**Mill Residuals**	**Total Balance**
Appalachian	(10,000)	3,215,000	1,984,000	5,911,000	11,100,000
Great Lakes/Midwest	3,000	4,233,500	901,000	54,500	5,192,000
Inland West	(6,000)	1,101,000	1,688,000	2,213,000	4,996,000
Northeast	21,000	7,748,000	991,000	(112,000)	8,648,000
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South/Western Zone	(9,000)	54,000	3,188,000	1,379,000	4,612,000
Southwest	0	144,000	81,000	(6,000)	219,000
Total	**(15,000)**	**20,625,500**	**20,286,000**	**15,471,500**	**56,341,000**

2.3.1 National Results & Regional Patterns

Under current operating conditions, the analysis identifies a net national surplus of approximately 56.34 million BDT per year, concentrated almost entirely in pulpwood/small diameter roundwood (20.6 million BDT), logging slash (20.2 million BDT), and mill residuals (15.4 million BDT). Consistent with a key assumption in the analysis, sawtimber remains effectively balanced at the national and regional levels.

> ***Key Insight: This pattern suggests that existing surplus conditions are not driven by excess sawlog production, but rather by limited market demand for the cogenerated fiber streams.***

At the regional level, the largest total surpluses occur in the Appalachian (11.1 million BDT) and South/East (10.5 million BDT) regions, followed by the Pacific Northwest (6.4 million BDT) and Northeast (8.6 million BDT). The Southwest shows only a modest surplus (0.2 million BDT), reflecting more limited forest productivity and industrial throughput. Across nearly all regions, pulpwood and logging slash dominate the surplus, while mill residuals exhibit moderate surpluses with isolated regional deficits—an indicator of localized competition for by-product feedstocks.

Data on the usage of logging slash are not readily available. However based on BECK's experience and judgment on its utilization as boiler fuel, logging slash demand is minimal nationwide (1.3 million BDT of demand versus 21.6 million BDT of supply). This finding confirms that the vast majority of slash generated through commercial harvesting and fuels reduction treatments goes unutilized. This outcome is not unexpected, as logging slash is generally costly to recover, transport, and process, and is not an appropriate feedstock for most existing utilization pathways because of small piece size, mixed composition of materials, contamination, moisture content, and low bulk density. As a result, slash tends to be excluded from higher-value manufacturing systems, leaving it concentrated in low-value or non-market outlets such as pile burning or in-woods disposal.

2.3.2 Infrastructure Capacity Versus Market Demand

To stress-test whether the observed surplus is driven more by market demand or installed processing capacity, we evaluated a hypothetical scenario in which all facilities operate at 100% of nameplate capacity. This allows for testing whether surplus conditions are constrained by infrastructure capacity or by market demand. The scenario evaluated assumed that all installed manufacturing facilities operate at 100% capacity utilization. Under that full-capacity case, total annual fiber demand would increase to approximately 295.2 million BDT, at which point the system would shift from surplus to a net national fiber deficit of approximately 25.7 million BDT per year. This deficit would include a 40.0 million BDT/year shortfall in sawtimber supply and a 6.1 million BDT/year shortfall in pulpwood, partially offset by a 21.0 million BDT/year surplus in logging slash. Once again, it is worth noting that logging slash is a feedstock ill-suited for most utilization pathways. Where it is suitable, other materials (such as mill residuals) are often available at a lower cost.

> ***Key Insight: This full-capacity scenario demonstrates that manufacturing infrastructure in most regions is not the primary limiting factor in fiber utilization. Instead, the bottlenecking constraint is insufficient market demand and product off-take for pulpwood, logging slash, and mill residuals.***

In other words, lack of market demand is the limiting constraint rather than a lack of installed processing equipment. In most regions, the physical capacity to process fiber already exists, but current product markets do not provide sufficient price support or volume demand to fully absorb the mill residuals, pulpwood, and logging slash generated by economically justified sawtimber harvests.

In addition to market demand, utilization outcomes are influenced by the availability of skilled labor and dependable logging and hauling contractors. In some regions, labor constraints, aging contractor bases, and rising logging and transportation costs can effectively limit realized processing throughput, even where installed capacity exists.

Together, these results indicate that the national fiber imbalance is fundamentally a market structure problem, not a harvest availability or infrastructure capacity problem. In most regions, expanding utilization will therefore depend less on simply adding incremental processing equipment and more on developing scalable, durable markets and products capable of absorbing large volumes of low-value pulpwood, logging slash, and mill residuals generated through restoration and commercial harvest activities. Another possible change factor is technologies that reduce the costs of harvesting, processing, and transport, which would in turn reduce the raw material cost and potentially improve the economic structure of certain utilization pathways.

This analysis is situated within the broader forestry and forest products manufacturing ecosystem, but its primary focus is on identifying where and how the utilization of small diameter roundwood and mill residuals can be increased. These by-products of forest restoration, fuels reduction treatments, and sawmilling represent the most abundant and least utilized portions of the wood resource base across much of the United States.

Finally, harvest estimates are derived from FIA data, which represent the most comprehensive and nationally consistent source of forest inventory information. As with any large-scale inventory system, FIA data are subject to sampling error, reporting lag, and periodic remeasurement cycles, which can extend up to a decade in some regions. While FIA data may not capture short-term market fluctuations or fine-scale local dynamics, it provides a robust and internally consistent foundation for comparative regional analysis. More granular data at the state, county, ownership, or ownership-class level are available for users seeking to conduct more localized assessments.

2.4 UNUTILIZED GROWTH, MORTALITY, & RESOURCE DYNAMICS

The relationship between forest growth, harvest, and mortality provides a critical measure of overall forest condition and utilization efficiency across regions. Accordingly, **Table 2.2** summarizes regional differences in forest growth, harvest, mortality, and unutilized growth, based on U.S. Forest Service Forest Inventory and Analysis (FIA) data. *Gross Growth* represents the gross annual biological accumulation of wood volume. *Harvest* reflects removals for wood products. *Mortality* is shown separately to illustrate the magnitude of natural losses. It captures natural losses due to insects, disease, fire, drought, and competition. To understand how much gross annual growth is unutilized, the formula is: Gro*ss Annual Growth minus Harvest minus Mortality = Unutilized Growth.*

Table 2.2 – Gross Growth, Harvest, Mortality, & Effective Growth by Subregion (BDT/Year)

Region	Gross Growth	Harvest	Mortality	Unutilized Growth
Appalachian	104,904,563	20,678,680	37,240,776	46,985,107
Great Lakes/Midwest	56,990,258	17,310,176	22,009,713	17,670,369
Inland West	33,237,226	17,200,547	43,255,261	(27,218,582)
Northeast	68,368,121	20,347,700	27,752,612	20,267,809
Pacific Northwest	46,371,512	27,133,516	10,388,089	8,849,907
South/Central Zone	108,060,791	40,180,160	18,335,353	49,545,278
South/East Zone	159,009,231	71,358,607	38,903,503	48,747,121
South/Western Zone	99,517,812	32,776,706	18,730,492	48,010,614
Southwest	(2,286,190)	921,179	12,421,395	(15,628,764)
Total	**674,173,324**	**247,907,271**	**229,037,194**	**197,228,859**

Regionally, the South/East, South/Central, Appalachian, and South/Western zones show the highest unutilized growth, driven by strong biological productivity combined with predominantly private ownership, which increases access. The Great Lakes/Midwest and Northeast show moderate unutilized growth reflecting balanced ownership patterns and steady forest recovery dynamics. In contrast, the Inland West and Southwest show negative values for unutilized growth. This is driven by two reinforcing factors: high natural mortality and large shares of Federal ownership, both of which reduce accessibility to harvest under current policy conditions. The Pacific Northwest falls between the extremes, with moderate unutilized growth shaped by relatively high growth rates but constrained by Federal ownership shares.

Overall, the table illustrates that unutilized annual forest growth is positive in nearly all regions, but can vary significantly in scale. These differences are a critical backdrop for evaluating opportunities to expand use of small diameter roundwood and mill residuals, and for understanding the restoration and forest health needs that vary across the country.

Table 2.3 presents growth-to-drain (G:D) and mortality-to-drain (M:D) ratios for each region, providing a normalized view of forest utilization intensity and forest health stress. The G:D ratio relates net annual growth to harvest, and offer a scale-independent way to compare regions with very different forest sizes and production levels. Values greater than 1.0 indicate that growth exceeds harvest, while values near 1.0 indicate approximate balance. Values below 1.0 signal that harvest is exceeding easily accessible growth.

Across most regions, G:D values range from approximately 1.5 to 3.5, confirming that net annual growth substantially exceeds harvest in much of the country. The Appalachian, Great Lakes/Midwest, Northeast, and South/Western zones all exhibit particularly high G:D ratios, indicating sustained net accumulation and long-term underutilization of forest growth. The Pacific Northwest stands out with comparatively low G:D ratio, indicating a forest system that is much closer to balance between growth and harvest. In contrast, the Inland West and Southwest show negative G:D ratios which reflect excessive mortality rather than high harvest (as shown in Table 2.2).

The mortality-to-drain (M:D) ratio provides insight into forest health by comparing natural losses to harvest. Low M:D values (below 1.0) in the Southern and Pacific Northwest regions indicate that most volume reduction occurs through managed harvest rather than uncontrolled mortality. In contrast, the Inland West (M:D = 2.5) and especially the Southwest (M:D = 13.5) exhibit mortality rates that greatly exceed harvest. These findings underscore severe forest stress conditions driven by drought, insects, and wildfire—accompanied by little management activity to salvage the trees affected by natural mortality, or more proactively, to thin them to reduce the chances of mass mortality events. These regions represent some of the strongest candidates for restoration-linked utilization of small diameter roundwood.

Taken together, the G:D and M:D ratios show that while many regions continue to accumulate forest volume faster than it is being harvested, the mechanism of volume reduction varies sharply by region. In the eastern and southern U.S., growth dominates and harvest provides the primary outlet for material. In much of the Interior West and Southwest, mortality rather than harvest is the dominant driver of change, reinforcing the need for active management and expanded utilization pathways to convert forest health liabilities into economic and environmental assets.

Table 2.3 – Ratio Indicators (G:D and M:D)

Region	G:D	M:D
Appalachian	3.3	1.8
Great Lakes/Midwest	2.0	1.3
Inland West	(0.6)	2.5
Northeast	2.0	1.4
Pacific Northwest	1.3	0.4
South/Central Zone	2.2	0.5
South/East Zone	1.7	0.5
South/Western Zone	2.5	0.6
Southwest	(16.0)	13.5

It is important to note that the fiber supply-and-demand balances presented earlier in this chapter reflect current operating conditions including prevailing market demand, mill utilization rates, and recent harvest behavior. These balances should not be interpreted as representing biological or silvicultural limits on harvest. In most regions, as demonstrated in the preceding table, there is substantial unutilized forest growth, indicating that observed fiber surpluses are a function of forest management policy and market structure rather than resource scarcity.

Table 2.4 illustrates the theoretical ceiling on additional harvest potential, highlighting the scale of material that could enter the system if utilization pathways, market demand, and institutional alignment were to improve. As the data in the table shows, harvest could reach a total of 445 million BDT per year and still maintain parity in net annual growth and drain. The values in the rightmost column depict the combination of current harvest plus unutilized growth. As is evident, harvests could nearly double and remain sustainable.

Table 2.4 – Additional Harvest Required to Reach Effective Growth-to-Drain Levels of 1:1

Region	Current Harvest (BDT/Year)	Unutilized Growth (BDT/Year)	Theoretical Annual Harvest at G:D Parity (BDT/Year)
Appalachian	20,700,000	46,985,107	67,685,107
Great Lakes/Midwest	17,300,000	17,670,369	34,970,369
Inland West	17,200,000	-27,218,582	-10,018,582
Northeast	20,300,000	20,267,809	40,567,809
Pacific Northwest	27,100,000	8,849,907	35,949,907
South/Central Zone	40,200,000	49,545,278	89,745,278
South/East Zone	71,400,000	48,747,121	120,147,121
South/Western Zone	32,800,000	48,010,614	80,810,614
Southwest	900,000	-15,628,764	-14,728,764
Total	**247,900,000**	**197,228,859**	**445,128,859**

2.5 FIBER SUPPLY BY OWNERSHIP TYPE

This section provides data, analysis, and narrative explaining a) who controls the fiber and b) what portion is provided by publicly vs. privately owned forests. Ownership structure, in combination with the fiber balance results, defines both the opportunity and the mechanism for expanding utilization. Public ownership-heavy regions will rely more on policy and contracting tools, while private-ownership regions will depend on market incentives.

Accordingly, **Table 2.5** categorizes the annual supply by region and by the type of owner that produced the material. The owner categories include National Forest, other Federal/State/ local, and private ownership. Ownership patterns strongly influence accessibility, policy leverage, contractual structures, and investment risk, and therefore represent a critical dimension of regional readiness for expanded utilization.

Table 2.5 – Estimated Roundwood Harvest by Ownership Class & U.S. Subregion (BDT/Year)

Region	National Forest	Other Federal	State & Local	Private	Total
Appalachian	338,000	86,000	449,000	19,805,000	20,679,000
Great Lakes/Midwest	1,093,000	41,000	5,433,000	10,743,000	17,310,000
Inland West	2,518,000	263,000	2,120,000	12,300,000	17,201,000
Northeast	154,000	28,000	1,972,000	18,193,000	20,348,000
Pacific Northwest	1,600,000	723,000	4,014,000	20,797,000	27,134,000
South/Central Zone	453,000	58,000	581,000	39,088,000	40,180,000
South/East Zone	1,072,000	1,181,000	2,042,000	67,064,000	71,359,000
South/Western Zone	1,038,000	193,000	111,000	31,434,000	32,777,000
Southwest	606,000	21,000	20,000	274,000	921,000
Total	**8,872,000**	**2,594,000**	**16,742,000**	**219,698,000**	**247,909,000**

2.5.1 National & Regional Findings

At the national level, private lands overwhelmingly dominate the wood fiber supply, accounting for approximately 219.7 million BDT per year, or nearly 89% of total estimated supply. In contrast, State and local ownerships contribute 16.7 million BDT (approximately 7%), while National Forest lands account for 8.9 million BDT (approximately 4%). Other Federal lands represent a comparatively minor share nationally (2.6 million BDT).

At the regional level, ownership structure varies widely by region, reflecting fundamental differences in forest history, management regimes, and market structure:

- The *South/East Zone* and *South/Central Zones* are overwhelmingly private-land-driven, with private ownership accounting for the vast majority of supply (67.1 million BDT and 39.1 million BDT, respectively). These regions exhibit strong alignment between private fiber control and private industrial infrastructure, reinforcing their role as the most production-intensive forest products regions in the country.
- The *Great Lakes/Midwes*t and *Northeast* regions also show strong private and State/local ownership dominance, reflecting extensive county forest systems and non-industrial private forest (NIPF) management. These ownership patterns support high accessibility to small diameter and residual material, but also introduce parcelization, landowner coordination, and price sensitivity challenges for large-scale deployment.

- In contrast, the *Inland West, Pacific Northwest, and Southwest* regions all exhibit much higher public-land influence. In the Inland West, public ownership (National Forest, State, and local) exceeds 4.6 million BDT per year, representing a substantial portion of regional supply. The Pacific Northwest similarly shows over 6.3 million BDT per year produced under public ownership, while the Southwest, given it high proportion of public ownership, is heavily influenced by Federal land management despite its comparatively small overall harvest volume.
- The *Appalachian* region reflects a mixed *ownership* structure, with a modest Federal presence but a strong private base, supporting both localized restoration activity and conventional industrial markets.

2.5.2 Implications for Utilization Expansion

These ownership patterns have several important implications for expanding small diameter roundwood and mill residual utilization:

- Private-land-dominated regions (primarily the South and eastern U.S.) offer the greatest near-term scalability through conventional market mechanisms, but utilization expansion is tightly linked to product pricing, mill economics, and private landowner participation rather than public policy alone.
- Public-land-influenced regions (Inland West, Pacific Northwest, Southwest) exhibit strong alignment between forest restoration objectives and fiber availability, but face structural challenges related to permitting, implementation pace, contracting complexity, and stewardship capacity. In these regions, public funding, policy alignment, and long-term offtake certainty play a disproportionately large role in supporting utilization investment.
- The geographic overlap between public-land dominance and large logging slash surpluses reinforces the conclusion that restoration-driven material flows remain weakly connected to durable markets despite substantial physical supply.

Overall, the supply-by-ownership data demonstrate that while total fiber availability is driven primarily by private lands, many of the regions with the strongest forest health and wildfire risk imperatives are also those with the highest public-land influence and the greatest co-product surplus. As a result, ownership structure emerges as a central factor shaping both the feasibility and form of utilization expansion, influencing whether growth is likely to be market-driven, policy-dependent, or dependent on public/private partnership models.

2.6 MILL RESIDUAL SUPPLY

Mill residuals generally include chips, sawdust, planer shavings, and bark, generated during the conversion of roundwood raw material inputs into finished products. Most mill residuals are produced at sawmills, but other utilization pathways also produce residuals. Regardless, the mill residuals represent an essential component of the fiber supply available for expanded utilization and/or market development. Unlike logging slash or small diameter roundwood, mill residuals are already processed, size-reduced, and concentrated at manufacturing sites. This makes them among the most cost-efficient and operationally attractive feedstocks in the forest products sector. **Table 2.6** summarizes estimated annual mill residual production by region and type.

Table 2.6 – Estimated Mill Residual Production by Subregion & Mill Residual Type (BDT/Year)

Region	Chips	Sawdust	Planer Shavings	Bark	Total
Appalachian	5,112,000	820,000	4,000	941,000	6,877,000
Great Lakes/Midwest	1,651,000	352,000	105,000	354,000	2,462,000
Inland West	2,790,000	800,000	533,000	1,014,000	5,137,000
Northeast	1,977,000	361,000	53,000	390,000	2,781,000
Pacific Northwest	3,624,000	1,261,000	822,000	1,059,000	6,765,000
South/Central Zone	4,067,000	1,135,000	637,000	1,170,000	7,009,000
South/East Zone	5,897,000	1,650,000	917,000	1,663,000	10,127,000
South/Western Zone	3,765,000	1,091,000	647,000	1,133,000	6,636,000
Southwest	149,000	24,000	16,000	73,000	262,000
Total	29,032,000	7,494,000	3,734,000	7,797,000	48,056,000

2.6.1 Mill Residual Composition

As the data show, across all regions, mill residuals total an estimated 48.1 million BDT per year, comprising:

- Chips: 29.0 million BDT (60% of total residuals)
- Sawdust: 7.5 million BDT (16%)
- Planer shavings: 3.7 million BDT (8%)
- Bark: 7.8 million BDT (16%)

The dominance of chips reflects the consistent breakdown of sawlogs in primary manufacturing and the ongoing need for wood chips in pulp, panel, and bioenergy sectors. Note that mill residuals constitute a portion of the sawtimber supply in the supply and demand balance. In other words, the mill residuals are primarily generated when sawtimber is converted into primary products such as lumber and veneer.

2.6.2 Regional Patterns of Mill Residual Production

Residual production closely mirrors regional sawtimber harvest volumes and sawmill concentrations, with several notable patterns:

- The South/East Zone produces the largest volume (10.1 million BDT), reflecting its extensive sawmill infrastructure and high levels of industrial timber harvest.
- The South/Central Zone (7.0 million BDT) and Pacific Northwest (6.8 million BDT) follow, consistent with their strong sawmill sectors and diversified wood products industries.
- The Appalachian (6.9 million BDT) and South/Western (6.6 million BDT) regions also exhibit sizable residual streams, supporting both traditional and emerging product pathways.
- Regions with lower sawmilling intensity, such as the Southwest (0.26 million BDT), generate comparatively small volumes of mill residuals.

These residual volumes are directly tied to sawlog consumption, which in the modeling framework is assumed to be equal to sawtimber demand. This reflects the reality that sawtimber-sized trees are generally harvested only when markets exist for them.

2.6.3 Implications for Utilization Potential

As a general rule, mill residuals are the most readily usable component of the fiber surplus for several reasons:

- Operational ease: Residuals are already collected at industrial sites, reducing handling, transportation, and processing costs relative to logging slash or in-woods SDR.
- Market diversity: Chips, sawdust, and bark have broad applications across pulp and paper, panel manufacturing, pellets, engineered wood products, and bioenergy markets.
- Quality consistency: Residuals result from controlled industrial processes, making them more suitable for technologies requiring moisture consistency and size uniformity.
- Scalability: Regions with large sawtimber harvests and robust sawmilling clusters (e.g., the South/East, South/Central, and Pacific Northwest) provide dense, steady supplies that support long-term investment.

2.6.4 Relationship with the Regional Fiber Surplus

Although mill residuals represent a 14.5 million BDT/year surplus nationally (from the fiber balance analysis), this surplus varies regionally:

Large residual-producing regions tend to have strong existing markets, yet still exhibit surpluses due to limited pulp, energy, or composite panel demand. As demonstrated in Section 2.3.2, these residual surpluses persist primarily due to limited market demand rather than a lack of installed processing capacity.

In certain regions (e.g., parts of the Northeast and Great Lakes), residual deficits or near-balance conditions may indicate localized competition among mills or constraints in the pulp and paper sector.

In combination with the analysis of SDR and slash, mill residual dynamics highlight where near-term, low-cost growth opportunities exist for new pathways and where market saturation or feedstock competition might limit expansion.

2.7 INDUSTRIAL INFRASTRUCTURE & UTILIZATION EFFICIENCY

Table 2.7 displays a listing of forest products mills in the U.S. by region and mill type. This national mill infrastructure dataset (provided courtesy of FORISK) highlights the uneven distribution of processing capacity across the United States. Of the approximately 1,800 active mills, nearly half are softwood and hardwood lumber mills, with the remainder spread among pulp and paper, veneer/plywood, chip mills, pellets, OSB, composite panels, bioenergy, and a small but growing set of mass timber and EWP facilities. Note that bioenergy facilities, as referenced in this report, include both stand-alone power generation facilities and combined heat and power (CHP) systems located at industrial sites.

The mill infrastructure dataset used in this analysis focuses on primary and secondary industrial facilities with meaningful throughput and regional market influence. While most large and mid-scale facilities are well represented, some smaller or highly localized operations such as pallet mills, cut stock producers, post-and-pole yards, and small mulch facilities might not be fully captured. These facilities typically operate at relatively small scales and serve localized markets. As a result, while they are important within specific communities, their aggregate fiber consumption is small relative to the volumes evaluated in this analysis and does not materially affect regional or national utilization conclusions.

Although hardwood and softwood mill counts are broadly comparable at the national level, U.S. softwood lumber production is approximately 35–40 billion board feet per year, while annual hardwood production has averaged about 5–6 billion board feet in recent years. As a result, the average hardwood mill operates at a significantly smaller scale than the average softwood mill. Hardwood mills have lower throughput and higher labor intensity per unit of wood processed. This structural distinction is particularly relevant in regions such as Appalachia, where employment is supported by numerous smaller, distributed hardwood mills rather than a smaller number of high-throughput facilities.

It is also important to note that EWP and mass timber plants primarily consume secondary products, such as kiln-dried lamstock and veneer, and do not draw directly on roundwood supply. This influences their roles in regional fiber balances. Also, in constructing the national supply-and-demand model, chip mill demand was discounted to 15% of capacity to avoid double-counting fiber already allocated to pulp mills, since chip mills often operate as intermediaries serving that sector.

Regionally, the South's dominance of overall mill counts reflects decades of plantation forestry investment and the concentration of large-scale lumber, pulp, paper, panel, and bioenergy manufacturing. The Appalachian region also contains plentiful mills, driven primarily by hardwood lumber production and downstream processing. In contrast, the Southwest and Inland West contain relatively few traditional sawmills but exhibit a disproportionately high share of bioenergy facilities, consistent with forest health-driven restoration programs and limited access to large-scale manufacturing infrastructure. The Pacific Northwest remains a national center for softwood lumber, veneer, plywood, and mass timber infrastructure, while the Great Lakes/Midwest and Northeast continue to support substantial pulp and paper capacity.

Table 2.7 – U.S. Forest Products Mill Infrastructure (Count of Mills by Region & Type)

Region	Chip Mills	Composite Panel Mills	Lumber Mills	EWP/ MT Mills	OSB Mills	Pellet Mills	Plywood / Veneer Mills	Pulp/ Paper Mills	Bio-energy Mills	Grand Total
Appalachian	10	0	185	2	2	16	5	11	24	255
Great Lakes/Midwest	0	2	63	1	2	13	12	17	41	151
Inland West	2	3	57	5	0	13	6	2	43	131
Northeast	13	1	106	2	1	24	7	10	54	218
Pacific Northwest	15	5	79	17	0	12	39	10	25	202
South/Central Zone	17	1	110	5	4	12	16	17	31	209
South/East Zone	32	5	174	3	11	34	19	35	81	379
South/Western Zone	13	5	101	5	10	14	15	16	29	227
Southwest	0	0	9	1	0	8	0	1	10	29
Total	**102**	**22**	**884**	**41**	**30**	**146**	**119**	**119**	**338**	**1,801**

Together, these patterns reveal a sector characterized by strong regional specialization and persistent mismatches between fiber availability, industrial scale, and utilization pathways. These mismatches are not uniform across regions; rather, they reflect decades of investment patterns, ownership structures, mill technologies, and market access that shape how wood is harvested, processed, and ultimately converted into economic value.

In some regions, fiber availability exceeds the capacity of existing industrial infrastructure. Areas with extensive forestland and active restoration or forest health programs, particularly in parts of the Inland West and Southwest, generate significant volumes of small diameter material and lower-grade sawtimber, yet have relatively few traditional sawmills or pulp facilities capable of processing that material at scale. In these cases, fiber surpluses persist not because of a lack of wood, but because available material does not align well with the size, technology, or product mix of nearby mills.

In other regions, fiber availability and processing capacity are present, but mill scale and technology limit throughput. For example, regions such as Appalachia contain many smaller, hardwood-oriented sawmills that are effective at recovering value from heterogeneous timber but operate at relatively low throughput per facility. This structure supports high employment and a strong secondary manufacturing base, but it can result in lower aggregate tonnage consumption compared with regions dominated by fewer, highly automated commodity mills. As a result, employment and economic output can be high even where modeled demand for fiber appears modest. Also, the hardwood sector has been under pressure for years as lower-cost substitutes have eroded market share, leading to mill closures and jeopardizing future demand.

A different form of mismatch occurs where industrial capacity is highly capital-intensive but narrowly focused. Regions such as the South/East Zone and parts of the Pacific Northwest host large pulp and paper mills, panel plants, and engineered wood product facilities capable of consuming substantial volumes of wood. While these facilities efficiently absorb fiber, they often depend on specific feedstock types, size classes, or quality specifications. Material that falls outside those specifications such as mixed-species small diameter roundwood, logging residuals, or restoration by-products can remain underutilized despite the presence of large manufacturing assets.

Additional mismatches arise from the structure of emerging utilization pathways. Newer pathways—including mass timber, engineered wood products, and certain bioenergy applications—do not always draw directly on roundwood supplies. Many rely on secondary products such as kiln-dried lamstock, veneer, or mill residuals, which can concentrate demand in regions with existing upstream infrastructure while bypassing areas with abundant standing timber but limited processing capacity. This dynamic helps explain why regions with growing interest in advanced wood products might not exhibit corresponding increases in roundwood demand.

Finally, transportation, ownership patterns, and market access further reinforce these mismatches. Fiber can be economically abundant yet functionally inaccessible due to haul distances, fragmented ownership, or insufficient aggregation points. Conversely, regions with strong logistics and market access might draw fiber from well beyond their immediate forest bases, decoupling local availability from local utilization.

2.7.1 National Patterns

At the national level, several key patterns emerge from the mill infrastructure data:

- Total industrial footprint: The United States supports approximately 1,800 active forest-sector mills, of which lumber mills (884) account for nearly half of all facilities, reflecting the continued central role of primary sawn wood production in the national supply chain.
- Southern concentration of capacity: The three Southern regions (South/Central, South/East, and South/Western Zones) collectively host more than 770 mills, representing the largest regional concentration in the country. This is a broad mix of lumber, veneer/plywood, pulp and paper, chip mills, pellets, and bioenergy, underscoring the South's role as the primary high-throughput wood-processing region.
- Limited scale of mass timber: Only 41 EWP and mass timber facilities operate nationwide, with the largest concentration in the Pacific Northwest and smaller clusters in the South and Inland West. Despite growing market interest, mass timber remains a small component of the national mill base and relies primarily on secondary wood products rather than direct roundwood consumption. EWP facilities are sparse and geographically concentrated, leaving substantial portions of the Northeast, Great Lakes, Appalachia, and Southwest with limited direct access to engineered wood manufacturing infrastructure. This spatial pattern contributes to regional mismatches between available fiber and emerging utilization pathways.
- Pulp and paper as a critical utilization system anchor: Pulp and paper mills (119 nationwide) remain essential sinks for low-grade roundwood and mill residuals, with significant concentrations in the South, Great Lakes/Midwest, and Northeast. This sector, while having suffered a significant decline in capacity, continues to play a stabilizing role in regional fiber markets.
- Expansion of energy pathways: The presence of 146 pellet mills and 338 bioenergy facilities reflects ongoing diversification toward energy and thermal markets. These facilities are

particularly prominent in the South and Southwest, where restoration-driven fiber supplies and limited traditional manufacturing capacity create demand for alternative utilization outlets.

- Strong regional specialization: Overall, the national mill landscape reflects deep regional specialization. Some regions are dominated by lumber and plywood production, others by pulp and paper, and others by biomass energy, resulting in structural mismatches between fiber availability, mill scale, and the utilization pathways currently in place.

2.7.2 Regional Patterns

At the regional level, mill distribution highlights how differences in scale, technology, and product mix shape regional utilization dynamics:

- Pacific Northwest: The Pacific Northwest hosts the highest concentration of mass timber and engineered wood facilities, along with the nation's strongest veneer and plywood base (39 mills). While the region is well positioned to serve mass timber and higher-value structural markets, fiber availability and log supply constraints limit the pace at which these pathways can expand.
- Southern Regions (Central, East, and Western Zones): The South collectively supports the largest mill base in the country, spanning nearly every major mill type. The region is particularly strong in lumber, pulp and paper, pellets, chip mills, and bioenergy, enabling high-throughput fiber utilization. Despite this scale, mass timber and EWP adoption remains limited relative to overall capacity, indicating potential alignment challenges between existing infrastructure and emerging markets.
- Great Lakes/Midwest: This region remains pulp- and paper-centric, with a moderate number of lumber mills and minimal representation in mass timber and EWP. While the region is effective at utilizing low-grade material, its infrastructure is less aligned with newer engineered-wood pathways despite a substantial forest resource base.
- Northeast: The Northeast exhibits a profile similar to that of the Great Lakes, with a strong pulp and paper and chip-mill presence and plenty of lumber mills. However, mass timber and EWP facilities remain scarce, creating a mismatch between abundant hardwood resources and access to higher-value utilization pathways.
- Appalachian Region: Appalachia contains abundant lumber mills (185), most of which are hardwood-oriented and relatively small in scale, along with a notable bioenergy presence (24 facilities). This distributed, labor-intensive structure supports high employment but limits aggregate throughput and contributes to lower overall fiber consumption relative to employment levels. The near-absence of EWP and mass timber facilities highlights a potential opportunity for targeted, regionally appropriate investment.
- Inland West: The Inland West supports a moderate number of lumber mills and a substantial bioenergy footprint, reflecting the influence of forest health and restoration programs. The region also shows a small but growing presence of EWP and mass timber facilities, suggesting closer alignment between restoration-driven fiber supplies and emerging utilization pathways than in many other regions.

2.7.3 Public Investment Patterns (USFS Grants)

Table 2.8 summarizes U.S. Forest Service grant investments between 2023 and 2025, totaling approximately $136 million nationwide. Unlike employment and mill infrastructure, which reflect decades of private-sector development, these investments provide a near-term indicator of where Federal policy is prioritizing intervention to address structural gaps in the forest products system.

Importantly, the regional distribution of USFS grant funding is influenced not only by economic or industrial considerations, but also by the geographic distribution of National Forest System lands. Regions with extensive national forest ownership, particularly in the Inland West, Pacific Northwest, and Southwest, are naturally better aligned with USFS-administered programs. As a result, grant allocations tend to concentrate in areas where the Forest Service has both management responsibility and active forest health objectives, including fuels reduction, restoration, and hazardous fuels treatment.

Consistent with this pattern, the Inland West received the largest share of funding ($49.7 million), followed by the Pacific Northwest ($28.3 million) and the Southwest ($18.9 million). Together, these regions account for more than 70% of total USFS investment, despite representing a smaller share of national forest-products employment and mill capacity. In these regions, grant funding is frequently used to support biomass utilization, small diameter processing, and emerging pathways intended to address restoration-driven fiber surpluses that are poorly matched to existing industrial infrastructure.

By contrast, regions with limited national forest ownership, particularly much of the South, received comparatively modest funding. This pattern does not reflect a lack of industrial activity or economic importance; rather, it reflects the fact that these regions rely predominantly on private timberlands and already possess extensive, market-driven processing capacity. As a result, fewer structural gaps exist that require Federal intervention through USFS grant programs, even where localized needs may still be present.

Regions such as Appalachia, the Great Lakes Midwest, and the Northeast occupy an intermediate position. These areas support substantial employment and mill infrastructure, but have more limited national forest acreage relative to western regions. USFS investments in these regions appear to be targeted toward specific bottlenecks, including mill modernization, residual utilization, or niche pathway development, rather than large-scale capacity expansion.

Taken together, these patterns indicate that USFS grant investments function as a corrective and place-based policy tool, shaped both by forest ownership and structural mismatches between fiber availability, industrial scale, and utilization pathways. Recognizing the role of National Forest geography is essential for interpreting regional investment patterns and for distinguishing between market-driven capacity and policy-driven intervention in the forest products sector. As a result, USFS grant investment patterns should be interpreted as indicators of policy-dependent intervention zones, rather than proxies for economic scale or market readiness.

Table 2.8 – USFS Grant Investment Patterns 2023-2025

Region	USFS Grant Investment (2023–2025 in $)
Appalachian	10,222,967
Great Lakes/Midwest	4,092,000
Inland West	49,690,808
Northeast	13,171,156
Pacific Northwest	28,325,195
South/Central Zone	1,000,000
South/East Zone	8,277,465
South/Western Zone	2,000,000
Southwest	18,893,503
Total	**135,673,094**

2.8 ECONOMIC CONTEXT & PUBLIC INVESTMENT ALIGNMENT

Regional employment, labor income, and GDP estimates in this section are based on data from the U.S. Bureau of Economic Analysis and related Federal economic datasets. The U.S. forest products sector represents a substantial component of the national economy, supporting approximately 1.26 million jobs, generating $93.0 billion in annual labor income, and contributing $153.7 billion in gross domestic product (GDP) annually across forestry, logging, manufacturing, and wood-based energy activities. Economic activity is unevenly distributed across regions due to differences in industrial structure, mill scale/capacity, infrastructure, and market access across regions. **Table 2.9** summarizes regional employment, labor income, and GDP, and provides context for interpreting regional scale and investment leverage.

Table 2.9 – Regional Scale of Forest Products Economy by Subregion

Region	Total Jobs	Total Labor Income ($/Year)	Total GDP ($/Year)
Appalachian	264,467	$19,564,957,966	$28,935,556,484
Great Lakes/Midwest	168,941	$12,591,431,716	$21,705,453,329
Inland West	122,804	$9,129,156,647	$14,412,714,150
Northeast	149,372	$12,297,600,224	$18,334,712,585
Pacific Northwest	68,111	$5,577,103,617	$10,410,744,431
South/Central Zone	83,398	$5,454,898,913	$9,874,816,625
South/East Zone	235,755	$17,074,902,578	$29,381,440,880
South/Western Zone	128,052	$8,823,229,976	$16,603,769,154
Southwest	39,120	$2,499,266,127	$4,017,033,031
Total	**1,260,020**	**$93,012,547,764**	**$153,676,240,669**

2.8.1 Regional Employment Footprint

Forest products employment is concentrated in a small number of regions with long-established manufacturing bases. The Appalachian region and the South/East Zone together account for nearly 500,000 jobs, representing roughly 40% of national forest-sector employment. Adding the Great Lakes/Midwest contributes an additional 169,000 jobs, bringing the combined total for these three regions to more than half of all forest products employment nationwide.

Appalachia's large employment footprint reflects its industrial structure: many smaller, hardwood-oriented mills and value-added processors that are more labor-intensive than highly automated, high-throughput commodity operations. The Northeast, Inland West, and South/Western Zone support moderate but economically important employment bases, while the Pacific Northwest, South/Central Zone, and Southwest have smaller regional footprints.

2.8.2 Labor Income Distribution

Regional labor income generally tracks employment but also shows differences in product mix and capital intensity. Appalachia leads nationally at $19.6 billion/year, followed by the South/East Zone at $17.1 billion/year. The Great Lakes/Midwest and Northeast each exceed $12 billion/year, reinforcing their roles as major manufacturing regions. Regions with smaller job counts but relatively high labor income (e.g., Pacific Northwest and Inland West) indicate a higher concentration of capital-intensive or higher-value activities.

2.8.3 Regional GDP Contribution

GDP further reflects regional differences in industrial structure. The South/East Zone and Appalachian region each generate roughly $29 billion/year in forest-sector GDP, together representing nearly 40% of the national total. The Great Lakes/Midwest contributes $21.7 billion/year, while the Northeast, Inland West, and South/Western Zone each contribute $14–$18 billion/year. Although several regions represent smaller shares nationally, forest products can remain locally significant economic drivers in rural and forest-dependent communities.

2.8.4 Implications for Regional Analysis

Taken together, the preceding analyses demonstrate that forest product utilization outcomes vary widely across regions due to structural differences in industrial scale, species mix, market alignment, ownership context, and utilization pathways, rather than differences in forest resource availability alone. Regions with similar levels of fiber supply can exhibit markedly different utilization performance depending on how existing infrastructure, market demand, and policy frameworks interact.

These findings indicate that fiber surpluses are not inherently indicative of unmet processing capacity, but instead reflect mismatches between the characteristics of available material and the types of products and markets currently served by regional mill infrastructure. In some regions, small and distributed mills support high employment but limited throughput, while in others, large capital-intensive facilities efficiently absorb fiber yet rely on narrow feedstock specifications.

As a result, regional opportunities to expand utilization are highly context-dependent. Effective interventions must be tailored to local conditions, accounting for the scale and configuration of existing infrastructure, the nature of available fiber streams, and the market pathways capable of converting that material into durable economic value. This regional differentiation provides the foundation for the composite readiness assessment presented in the following section.

2.8.5 Markets & Enabling Conditions

Industrial energy prices vary substantially across regions and represent a meaningful enabling (or constraining) factor for energy-intensive utilization pathways. As shown in **Table 2.10**, average industrial electricity prices range from roughly $0.065/kWh in parts of the South to >$0.14/kWh in the Northeast, while industrial natural gas prices range from < $5/MCF in parts of the South to > $10/MCF in the Pacific Northwest. These differences shape regional competitiveness and reinforce the importance of matching utilization pathways to local operating conditions rather than fiber availability alone.

Table 2.10 – Average Industrial Electricity & Natural Gas Prices by Subregion

Region	Average Cost of Power for Industrial Users ($/kWh)	Average Cost of Natural Gas for Industrial Users ($/MCF)
Appalachian	0.090	8.90
Great Lakes/Midwest	0.084	5.61
Inland West	0.103	7.57
Northeast	0.145	9.17
Pacific Northwest	0.076	10.82
South/Central Zone	0.068	4.75
South/East Zone	0.081	6.30
South/Western Zone	0.065	4.85
Southwest	0.082	6.54

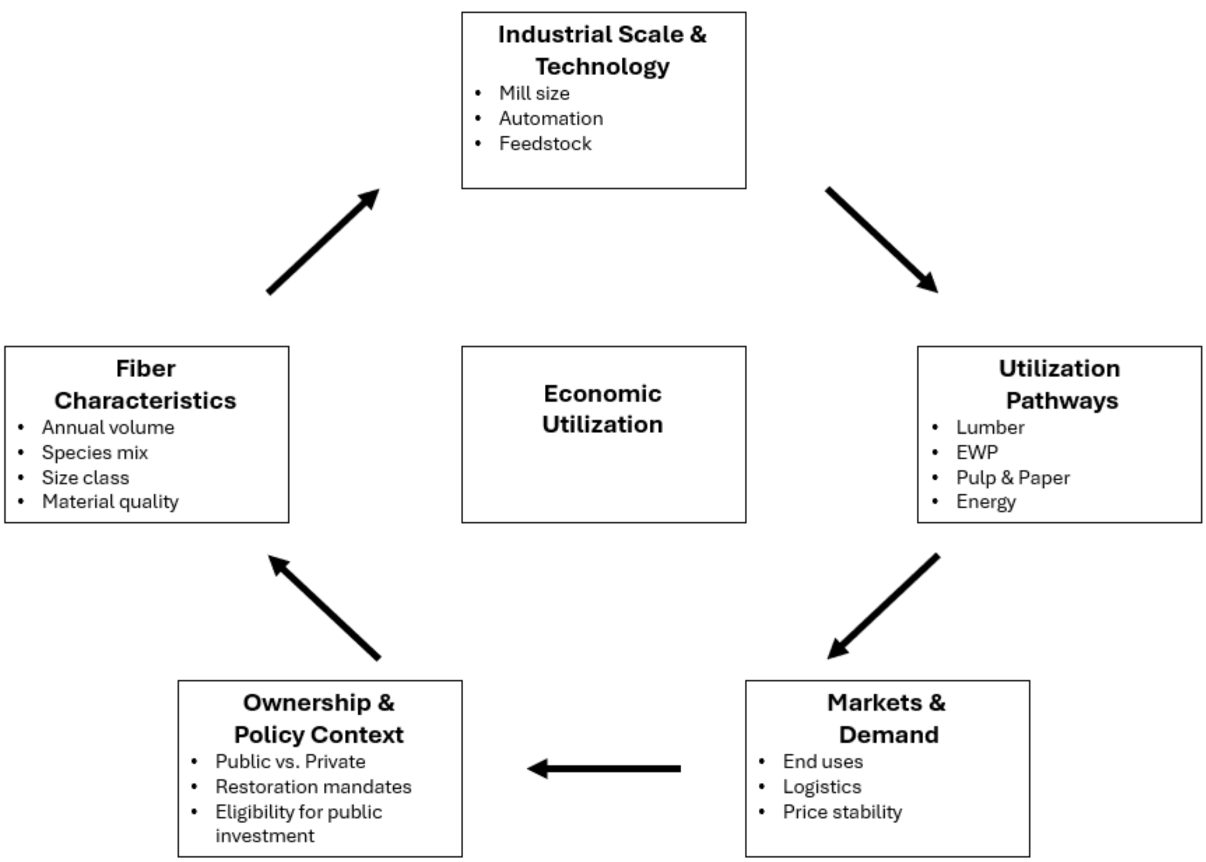
2.8.6 Structural Alignment & Persistent Underutilization

Across regions, the analysis indicates that underutilization of small diameter roundwood and mill residuals is driven not by any single limiting factor, but rather by misalignment among multiple structural elements within regional forest product systems. Effective utilization occurs only where fiber characteristics, industrial capacity, ownership, utilization pathways, and market demand are all aligned.

> ***Key Insight: In some regions, abundant fiber supplies—particularly small diameter material generated through forest health and restoration activities—are poorly matched to the scale, technology, or feedstock requirements of existing mills. In others, extensive industrial infrastructure efficiently processes large volumes of wood but depends on narrow species mixes, size classes, or product specifications that limit flexibility for alternative or emerging pathways. Species composition further influences these dynamics, as hardwood systems often support labor-intensive processing and secondary manufacturing, while softwood systems tend to align more readily with capital-intensive, high-throughput facilities.***

In this chapter, structural misalignment refers to situations where the components required for utilization exist, but are not aligned in scale, location, timing, or function to support durable, market-based use of available fiber. **Figure 2.1** illustrates this structural alignment framework.

Figure 2.1 – Structural Alignment in Wood Fiber Utilization



2.8.7 Structural Misalignment in Practice

Structural misalignment differs by region. In the Inland West and Southwest, large volumes of restoration-linked small diameter material are produced on public lands, but fiber characteristics (small piece size, mixed species, variable quality), limited industrial depth, and thin market access constrains durable utilization. As a result, many projects rely on public investment, temporary incentives, or low-value end uses such as energy.

In Appalachia, employment is high and mill density is substantial, but the system is dominated by smaller hardwood mills optimized for value recovery rather than high tonnage throughput. This supports jobs and secondary manufacturing, but limits the region's ability to absorb large volumes of low-grade material at scale.

In the Pacific Northwest, diversified infrastructure supports high-value pathways (including veneer/plywood and mass timber), yet utilization outcomes are shaped by log supply dynamics and operating costs. Favorable electricity pricing supports certain processing activities, while higher natural gas costs can constrain thermal-intensive pathways (such as drying) unless offset by alternative heat sources.

These examples illustrate why fiber surpluses cannot be interpreted as simple shortages of capacity or supply. Utilization outcomes reflect the alignment (or misalignment) of fiber characteristics, industrial structure, operating conditions, ownership context, and market demand—reinforcing the need for a multi-dimensional readiness framework.

2.9 COMPOSITE REGIONAL READINESS & STRUCTURAL FRAMEWORK

The preceding analysis demonstrates that no single indicator adequately explains wood fiber utilization outcomes. Instead, utilization potential reflects the combined influence of multiple structural factors. To support comparative evaluation across regions, these factors are integrated into a composite regional readiness framework that assesses the relative capacity of each region to support expanded, durable utilization of small diameter roundwood and mill residuals.

2.9.1 Regional Readiness & Structural Framework Methodology

The readiness framework evaluates five dimensions drawn from Sections 2.3 through 2.8. Together, these dimensions describe whether available fiber can be converted into durable utilization under current market, operating, and policy conditions:

- Fiber Availability and Characteristics: volume, size class, species mix, material quality
- Industrial Scale and Infrastructure Fit: mill density, scale, technology, pathway compatibility
- Market and Economic Context: employment base, GDP, energy cost conditions
- Ownership and Policy Context: public versus private forest share, role of public investment
- Utilization Diversity and Resilience: range of active pathways, reliance on single operations/technologies

For each dimension, BECK assigned qualitative ratings for each region: Stronger, Moderate/Mixed, or Emerging/Constrained.

- Stronger regions show broad consistency among fiber characteristics, industrial configuration, operating conditions, ownership context, and active pathways, enabling utilization that is largely market-driven.
- Moderate/Mixed regions show strengths in some dimensions but meaningful constraints in others; utilization opportunities tend to be more pathway-specific and sensitive to market, cost, or policy conditions.

- Emerging/Constrained regions exhibit multiple structural constraints that limit durable utilization at scale; expanded utilization typically depends on public investment, policy support, and/or new market development.

This assessment is intended as a comparative screening tool rather than a siting analysis. Conditions vary within regions, and facility-level economics can differ materially from regional averages. Ratings should therefore be interpreted as indicators of relative opportunity and constraint rather than project-level feasibility conclusions.

2.9.2 Relative Regional Readiness Results by Dimension

The following sections include each readiness dimension and the scoring of each region.

Fiber Availability & Characteristics

Stronger Alignment: The Inland West and Southwest exhibit strong alignment in this dimension, driven by large volumes of small diameter material generated through forest health and restoration activities. These regions also contain substantial quantities of low-grade and non-sawtimber material, although accessibility and material quality constraints remain significant.

Moderate/Mixed Alignment: The Appalachian, Great Lakes/Midwest, and Northeast regions display moderate alignment. While overall fiber availability is substantial, utilization potential is shaped by heterogeneous hardwood species mixes, smaller average log sizes in some subregions, and variability in material quality. These characteristics support certain value-added pathways but limit compatibility with standardized, high-throughput applications.

Emerging or Constrained Alignment: The Pacific Northwest and Southern regions generally exhibit more constrained alignment for small diameter roundwood and low-grade material at the regional scale. Although total timber volumes are high, a larger share of the resource is oriented toward sawtimber and established markets, with less relative availability of surplus small diameter material outside of specific subregions.

Industrial Scale & Infrastructure Fit

Stronger Alignment: The South (Central, East, and Western Zones) demonstrates strong alignment due to its extensive and diversified industrial base, including large-scale lumber, pulp and paper, panel, pellet, and bioenergy facilities. This infrastructure supports high-throughput utilization of multiple fiber streams.

Moderate/Mixed Alignment: The Pacific Northwest, Great Lakes/Midwest, and Northeast exhibit mixed alignment. These regions possess substantial processing capacity, but it is often specialized or oriented toward particular feedstock types, limiting flexibility for absorbing diverse or low-grade material streams.

Emerging or Constrained Alignment: The Appalachian, Inland West, and Southwest regions display more constrained alignment. Appalachia's infrastructure is dominated by smaller, labor-intensive hardwood mills with limited aggregate throughput, while the Inland West and Southwest lack sufficient scale and capacity in traditional processing infrastructure to fully absorb available fiber.

Market & Economic Context

Stronger Alignment: The Southern regions and Great Lakes/Midwest show stronger alignment due to large employment bases, significant GDP contribution from forest products, and relatively favorable industrial energy costs. These conditions support market-driven utilization across multiple pathways.

Moderate/Mixed Alignment: The Appalachian and Pacific Northwest regions exhibit mixed alignment. Appalachia benefits from a large employment base but faces higher energy costs for certain thermal-intensive pathways, while the Pacific Northwest combines favorable electricity pricing with higher natural gas costs, shaping which utilization pathways are economically viable.

Emerging or Constrained Alignment: The Northeast, Inland West, and Southwest show more constrained alignment. Higher operating costs, limited regional market depth, and/or reliance on public investment reduce the competitiveness of energy-intensive or low-margin utilization pathways.

Ownership & Policy Context

Stronger Alignment: The Inland West, Pacific Northwest, and Southwest exhibit strong alignment in this dimension due to extensive public forest ownership and active Federal investment supporting forest health and utilization objectives.

Moderate/Mixed Alignment: The Northeast and Appalachian regions show mixed alignment, with a combination of public and private ownership and more targeted public investment focused on specific bottlenecks rather than system-wide capacity expansion.

Emerging or Constrained Alignment: The Southern regions and Great Lakes/Midwest display more constrained alignment from a policy perspective. These regions are dominated by private ownership and market-driven investment, with limited reliance on public intervention for utilization despite their large industrial scale.

Utilization Diversity & Resilience

Stronger Alignment: The South demonstrates strong alignment, supported by a wide range of active utilization pathways and reduced reliance on any single market sink. This diversity enhances resilience to market fluctuations.

Moderate/Mixed Alignment: The Pacific Northwest, Great Lakes/Midwest, and Appalachian regions exhibit moderate alignment. Each supports multiple pathways, but utilization is often concentrated in a limited set of dominant markets, increasing sensitivity to shifts in demand.

Emerging or Constrained Alignment: The Inland West, Northeast, and Southwest show more constrained alignment, where utilization depends heavily on a small number of pathways such as biomass energy or pulp. This limits resilience and increases exposure to policy or market changes.

2.10 KEY FINDINGS & IMPLICATIONS

The analyses presented in this chapter reveal consistent patterns across regions that help explain why significant volumes of small diameter roundwood and mill residuals remain underutilized despite substantial forest resources and industrial presence. The key findings below synthesize these patterns and highlight their implications for identifying viable, region-appropriate utilization strategies.

1. *Fiber availability alone does not determine utilization outcomes.* Across all regions, substantial volumes of small diameter roundwood and mill residuals coexist with persistent surplus conditions. This pattern indicates that underutilization is not primarily a function of insufficient supply, but rather reflects structural misalignment among fiber characteristics, industrial scale, markets, and policy context.
2. *Industrial scale and pathway compatibility are central determinants of effective utilization.* Regions with large, diversified, and high-throughput processing infrastructure are better positioned to absorb low-grade material, while regions dominated by smaller or highly specialized facilities face constraints even when fiber is abundant. Scale, technology, and feedstock specifications strongly influence utilization pathways' viability.
3. *Species mix and material quality materially shape utilization potential*. Diverse-species hardwood systems and material streams with higher contamination or variability support different (and often more labor-intensive) utilization pathways than the simpler species mixes found commonly found among softwood systems. These characteristics, combined with labor intensity (and

associated vulnerability to international competition), limit the transferability of utilization models across regions, and underscore the need for region-specific pathway selection.

4. *Market and operating conditions constrain utilization as much as physical infrastructure.* Employment base, GDP contribution, and industrial energy costs vary widely by region and directly affect the feasibility of energy- and capital-intensive utilization pathways. Even where infrastructure exists, unfavorable operating conditions can prevent durable market-driven utilization.

5. *Ownership structure and public investment influence where utilization occurs*. Regions with extensive public forest ownership, particularly in the western United States, exhibit strong linkages between forest health objectives and utilization activity, often supported by Federal investment. In contrast, regions dominated by private ownership rely more heavily on market signals and exhibit fewer policy-dependent mechanisms to address low-value material streams.

6. *Utilization diversity enhances system resilience*. Regions supporting a broad range of utilization pathways are less vulnerable to market volatility or policy shifts affecting any single end use. Conversely, regions dependent on a limited number of sinks, such as biomass energy or pulp/paper, face heightened exposure to demand disruptions.

7. *Public investment aligns with forest management context but does not fully resolve structural constraints*. Federal investment patterns correspond strongly with the location of national forests and forest health priorities. However, investment alone cannot overcome mismatches related to scale, market access, species composition, or operating costs, reinforcing the importance of targeted rather than uniform intervention.

8. *Effective utilization strategies must be pathway- and region-specific*. The composite readiness assessment demonstrates that no single utilization approach is universally applicable. Successful expansion of small diameter roundwood and mill residual utilization depends on aligning specific pathways with regional structural conditions rather than pursuing generalized capacity expansion.

The following chapter builds directly upon this regional readiness assessment by examining how different wood fiber utilization pathways align with these structural conditions, rather than assuming that all technologies are universally applicable.

CHAPTER 3 – KEY MARKET & INVESTMENT OPPORTUNITY ANALYSIS

3.1 OVERVIEW & ANALYTICAL SHIFT

As demonstrated in Chapter 2, regional fiber surpluses reflect structural misalignment rather than biological supply constraints. Chapter 3 builds on these findings by examining how different utilization pathways align (or fail to align) with those regional conditions.

To address this question, Chapter 3 applies a technology and pathway alignment framework that compares utilization pathways across a consistent set of dimensions, including market role, feedstock compatibility, required operating scale, geographic alignment, and policy dependence. This framework provides a structured way to interpret why certain pathways repeatedly struggle to scale up in response to prevailing conditions, while others play more durable or system-level roles.

3.2 FROM STRUCTURAL MISALIGNMENT TO PATHWAY ALIGNMENT

The structural misalignment identified in Chapter 2 provides the foundation for evaluating utilization pathways. Fiber characteristics such as piece size, species mix, moisture content, and spatial distribution vary widely by region and by ownership. Likewise, existing industrial infrastructure reflects decades of investment decisions that favored specific products, scales, and markets. Utilization outcomes emerge from the interaction of these elements rather than from any single factor in isolation.

As a result, utilization pathways are not interchangeable. Technologies differ not only in the products they produce, but in the roles they play within regional systems. Some pathways anchor large volumes of material and define the overall structure of fiber flow. Others absorb surplus material opportunistically, generate high value at limited scale, or represent emerging opportunities that are not yet positioned for system-wide impact.

Understanding these differences is essential for moving from diagnosis to opportunity. Rather than asking whether a given utilization technology is technically feasible, the more relevant question is whether it is structurally aligned with:

- The type of fiber available
- The scale at which material is generated
- The economic and policy conditions under which it must operate

Chapter 3 addresses this question by reframing technologies according to function and alignment rather than novelty or technical sophistication.

3.3 TECHNOLOGY & PATHWAY ALIGNMENT FRAMEWORK

The analysis in this report section does not attempt to identify preferred technologies or projects; instead, it interprets how different utilization pathways align with the structural conditions identified in Chapter 2. The technology and pathway alignment framework is used to compare a set of utilization pathways across common dimensions that influence market viability and investment relevance. These dimensions include market size, feedstock fit and volume requirements, geographic alignment, policy and regulatory context, and high-level financial characteristics. The framework is designed to reveal patterns and tradeoffs among technologies that are difficult to observe when technologies are evaluated individually.

The technology matrix is not a screening or ranking tool, nor does it identify preferred or recommended technologies. Instead, it functions as a structured reference that organizes a broad universe of utilization pathways according to shared characteristics—such as market role, feedstock requirements, scale, and policy dependence. The matrix is used in this chapter as an analytical lens to interpret patterns of alignment and misalignment, not as a mechanism for technology selection.

A broader universe of utilization technologies was reviewed as part of this analysis and is documented separately (see **Appendix 1 – Universe of Utilization Technologies Considered** and **Appendix 2 – Technology & Pathway Alignment Matrix**). The pathways included in the alignment framework represent those most relevant to current regional surplus conditions and investment questions. By focusing on comparative alignment rather than selection, the framework helps narrow the field of plausible pathways while preserving flexibility for region-specific strategies and future innovation.

3.4 MARKET ROLES OF UTILIZATION PATHWAYS

One of the clearest insights from applying the alignment framework is that utilization pathways play fundamentally different roles within regional wood utilization systems. These market roles describe how pathways function within the broader system, not their relative desirability or feasibility in any specific region. **Table 3.1** groups the universe of wood fiber utilizing technologies into four categories *based on their primary market role*, rather than by end product or technical category.

Table 3.1 – Technology Pathways & Their Market Roles

Technology Type	System Anchors	Volume Absorbers	Policy-Driven
Key Function	• Defines the core structure of regional wood utilization systems	• Consume large volumes of low-grade fiber but depend on anchors or policy	• Enable utilization where markets alone do not support delivered fiber costs (often tied to restoration, carbon, or energy policy)
Examples	• Sawn lumber • Pulp and paper • Structural panels	• Biomass power/CHP • Pellets/densified fuels • Thermal energy • Mulch/ground cover	• Biochar and carbon materials • Advanced biochemicals • Nanocellulose • Restoration-linked utilization supported by grants/ incentives
Why They Matter	• Drive sawtimber harvest • Generate most mill residuals • Anchor logistics, labor, and capital	• Absorb SDR, residuals, slash • Often marginal on price • Sensitive to energy costs and incentives	• Expand utilization in regions with structural constraints • Can unlock treatment pace and restoration outcomes • Typically not durable without ongoing incentives or policy support

As shown in the preceding table, at one end of the spectrum are the *System Anchors* that include pathways such as conventional sawmilling, pulp and paper manufacturing, and large-scale structural panel production. These define the basic structure of fiber flow. These anchors drive sawtimber harvest decisions, support high-throughput logistics, and generate most mill residuals as co-products. Where anchor industries are absent or weakened, downstream utilization options are typically constrained.

A second category includes *Volume Absorbers*, which can consume large quantities of low-grade fiber but often depend on anchor industries, favorable operating conditions, or policy support. Biomass energy, pellets, and certain landscaping products fall into this group. These pathways can play an important fiber utilization balancing role but are rarely sufficient on their own to anchor regional utilization systems.

Third, *Policy-Dependent Enable utilization where markets alone do not support delivered fiber costs (often tied to restoration, carbon, or energy policy).* Examples include biochar and advanced biochemicals.

This role-based framing clarifies why the presence of many technologies does not automatically translate into solutions for underutilization. It also sets the stage for examining how feedstock flexibility and operating scale further constrain which pathways can meaningfully address surplus conditions.

Finally, **Figure 3.1** summarizes a note about terminology in the report as it relates to classifying utilization pathways.

Figure 3.1 – Utilization Pathway Classification Framework

For clarity and consistency, utilization pathways in this report are classified by their primary market role, with secondary descriptors used only to provide additional context.

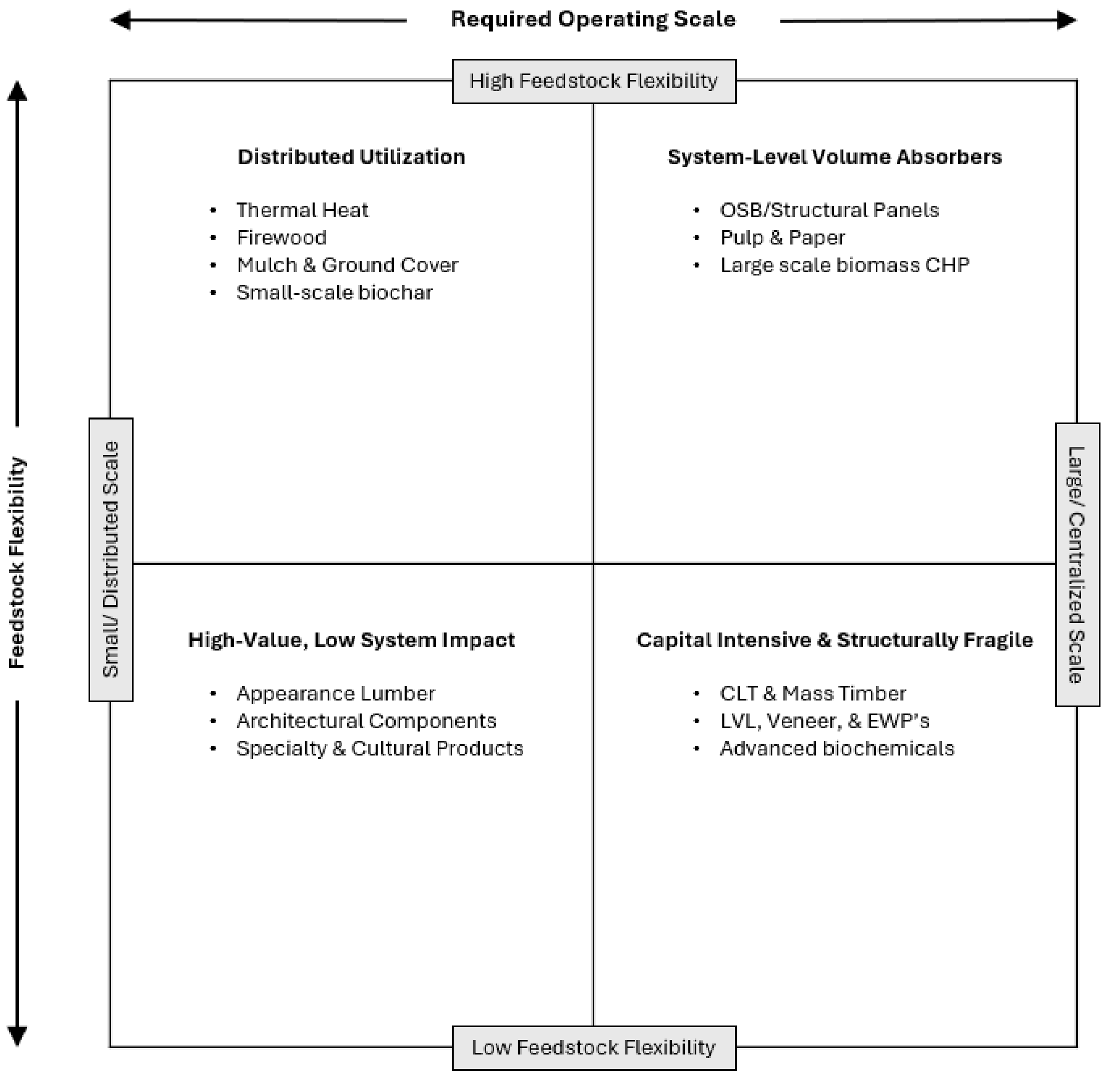
- **System Anchor Pathways** absorb large volumes of material at scale, establish durable market signals, and form the economic foundation of regional wood fiber systems.
- **Volume Absorber Pathways** can meaningfully reduce surplus material under appropriate conditions but lack the scale or durability to anchor markets independently.
- **Policy-Dependent Pathways** are capable of operating at scale but rely on sustained policy support or incentives to be economically viable.

Additional descriptors (e.g., niche, emerging, incremental) are used solely as qualifiers and do not represent distinct pathway categories.

3.5 FEEDSTOCK FIT & REQUIRED OPERATING SCALE

Beyond market role, the ability of a utilization pathway to materially reduce underutilized fiber depends on the interaction between feedstock specification flexibility and required operating scale. **Figure 3.2** illustrates this relationship by comparing utilization pathways based on the breadth of material they can accept and the scale at which they must operate to be economically viable.

Figure 3.2 – Feedstock Fit Versus Required Operating Scale



Feedstock flexibility is a binding constraint because the dominant surplus streams identified in Chapter 2 (including small diameter roundwood, logging slash, and mixed mill residuals) are inherently variable. They differ in species, piece size, moisture content, contamination, and spatial distribution. Pathways that tolerate this variability are better positioned to absorb surplus material, while those requiring narrow specifications face structural limitations regardless of technical maturity or product value.

Operating scale introduces a second constraint. Large, centralized facilities can process substantial volumes of material, but require consistent throughput to support capital recovery and operating costs. It can be challenging to maintain that consistency in regions where fiber supply is fragmented across ownerships, driven by restoration activity, or subject to policy uncertainty. As a result, pathways that combine narrow feedstock requirements with large scale tend to concentrate risk and face higher barriers to investment.

Table 3.1 highlighted three categories of utilization pathways distinguished by scale, feedstock flexibility, and market role. System anchor pathways, which combine broad feedstock flexibility with large operating scale, have the greatest potential to influence regional fiber balances and establish durable market signals.

However, they also face the highest capital, siting, and financing requirements. Volume absorber pathways typically operate at smaller scale but retain a degree of feedstock flexibility, allowing them to be deployed incrementally and adapted to local conditions. While these pathways can meaningfully reduce surplus material, they generally lack sufficient throughput to resolve large regional imbalances on their own. Policy-dependent pathways often involve either narrow feedstock requirements, large-scale operating assumptions, or both, and therefore face the greatest structural alignment challenges. As a result, these pathways frequently rely on sustained policy support or site-specific conditions and tend to advance more slowly or remain limited in scale relative to system anchors and volume absorbers.

This framework helps explain why many technically viable technologies remain limited in practice. Their constraints are structural rather than technical, rooted in mismatches between feedstock characteristics, operating scale, and regional conditions.

3.6 INSIGHTS FROM THE ALIGNMENT FRAMEWORK

Viewed collectively, the alignment framework reveals several consistent patterns that shape market and investment opportunity across regions.

- A small number of pathways anchor utilization systems. Conventional sawmilling, pulp and paper manufacturing, and large-scale structural panel production define the basic structure of fiber flow and generate most co-products. Many other pathways depend on these anchors for feedstock supply, logistics, and cost efficiency. Where anchor industries are absent or constrained, utilization options narrow quickly.
- Feedstock flexibility is often more important than product value. Pathways capable of tolerating mixed species, small piece size, and variable quality are better aligned with surplus conditions than higher-value pathways that require refined or uniform inputs. This helps explain why innovation and product sophistication alone have not resolved underutilization.
- Scale requirements concentrate risk. Large facilities can deliver significant impact, but only under conditions of stable supply, favorable logistics, and durable market demand. In regions dominated by public lands, restoration-driven harvesting, or heterogeneous forests, these conditions are difficult to guarantee, increasing reliance on policy support or long-term contracting.
- Most pathways play supporting rather than transformational roles. Niche, specialty, cultural, and artisan pathways provide meaningful local benefits and diversification, but their aggregate demand is small relative to regional surplus volumes. Emerging pathways hold long-term promise, but are not yet positioned to function as primary outlets for low-grade material.

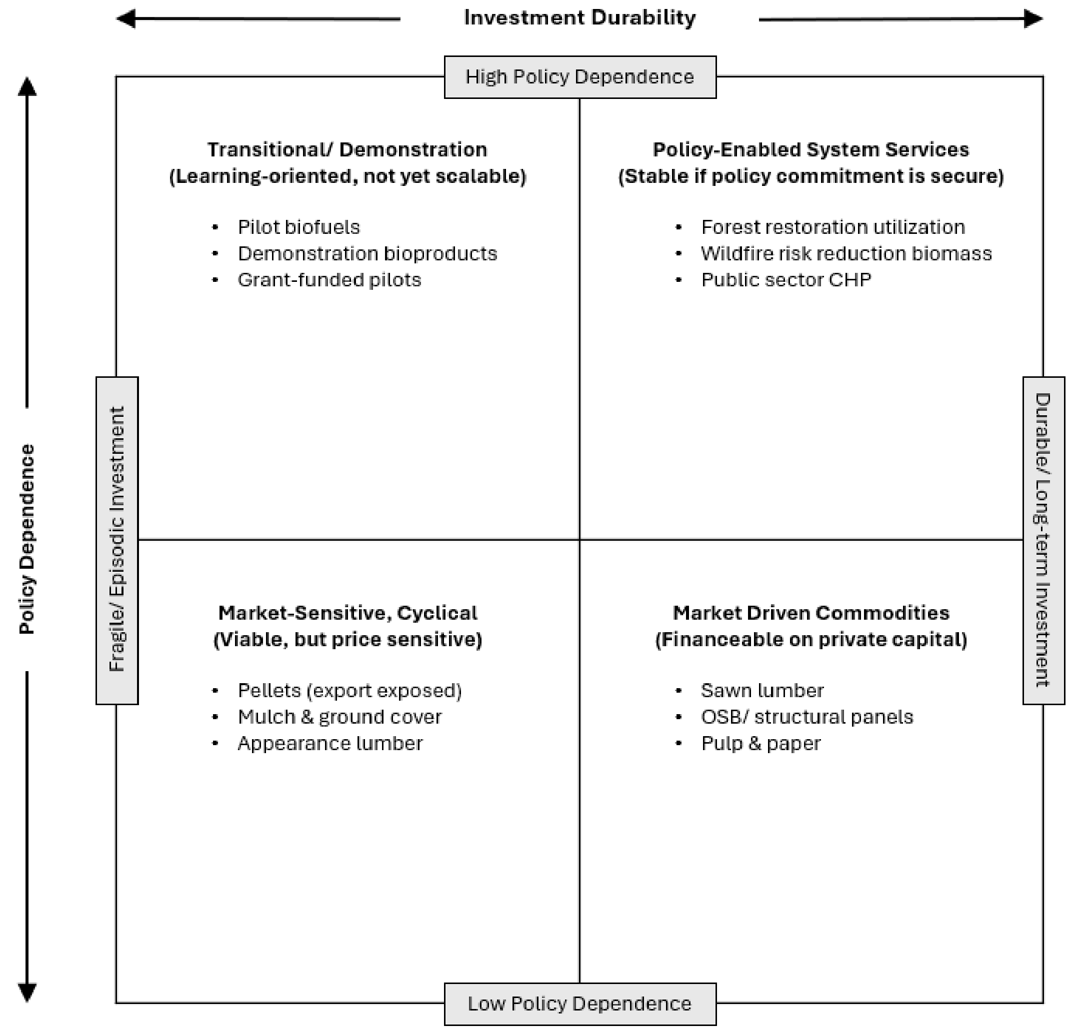
Finally, policy dependence represents a distinct category of opportunity. Many volume-absorbing pathways operate near or below market-clearing prices under current conditions. Their viability depends on public investment, incentives, or institutional mechanisms that offset cost disadvantages. These pathways should be evaluated using criteria that reflect public benefits and system outcomes, rather than purely private financial returns.

Together, these insights reinforce the conclusion that underutilization is driven by structural misalignment rather than a lack of ideas or technologies. Durable solutions depend on matching pathway characteristics to the materials which forests actually produce and the conditions under which that material can be mobilized.

3.7 POLICY DEPENDENCE & INVESTMENT DURABILITY

In addition to market role and feedstock alignment, utilization pathways differ fundamentally in their reliance on policy support and the durability of their investment case. **Figure 3.3** illustrates this distinction by grouping pathways according to the degree of policy dependence required for operation and the stability of the underlying demand or revenue stream.

Figure 3.3 – Policy Dependence & Investment Durability



At one end of the spectrum are market-driven and durable pathways, such as sawn lumber, structural panels, and pulp and paper manufacturing. These pathways operate primarily on market fundamentals and have demonstrated the ability to attract long-term private investment across multiple business cycles, even though they remain exposed to commodity price volatility.

A second group includes policy-dependent but durable system services, such as utilization tied to forest restoration, wildfire risk reduction, and public-sector combined heat-and-power systems. These pathways persist not because they maximize private returns, but because they deliver public benefits that justify ongoing institutional or policy support. When policy commitments are stable, these systems can support long-lived infrastructure and predictable utilization outcomes.

Other pathways occupy more fragile positions. Market-sensitive and cyclical pathways operate without direct subsidies but are highly exposed to price swings, export markets, or seasonal demand. These pathways can play important balancing roles, but their contribution to long-term utilization varies with market conditions. Finally, transitional and demonstration pathways are heavily policy-dependent and not yet positioned on a durable scale. These pathways are valuable for learning and innovation, but should not be expected to resolve near-term surplus conditions.

This framework reinforces the importance of aligning utilization strategies with appropriate financing and policy mechanisms. Market-driven pathways, policy-dependent system services, and demonstration-scale innovations each require different expectations, capital structures, and performance metrics. Treating these categories as interchangeable obscures risk and can lead to misaligned investment decisions.

3.8 MARKET SIZE CONTEXT: TAM, SAM, & SOM

In addition to structural alignment and investment characteristics, the potential of a utilization pathway to influence regional fiber outcomes depends on the size of the addressable market. Total Addressable Market (TAM), Serviceable Available Market (SAM), and Serviceable Obtainable Market (SOM).

- *Total Addressable Market* indicates the maximum theoretical market size. In other words, it is the market size when a product (or pathway) supplies 100% of all possible demand with no constraints.
- *Serviceable Available Market* is the portion of the total market actually reachable from where the fiber, mills, and infrastructure exist.
- *Serviceable Obtainable Market* is the portion of SAM that could be captured given competition, economics, and realistic deployment limitations.

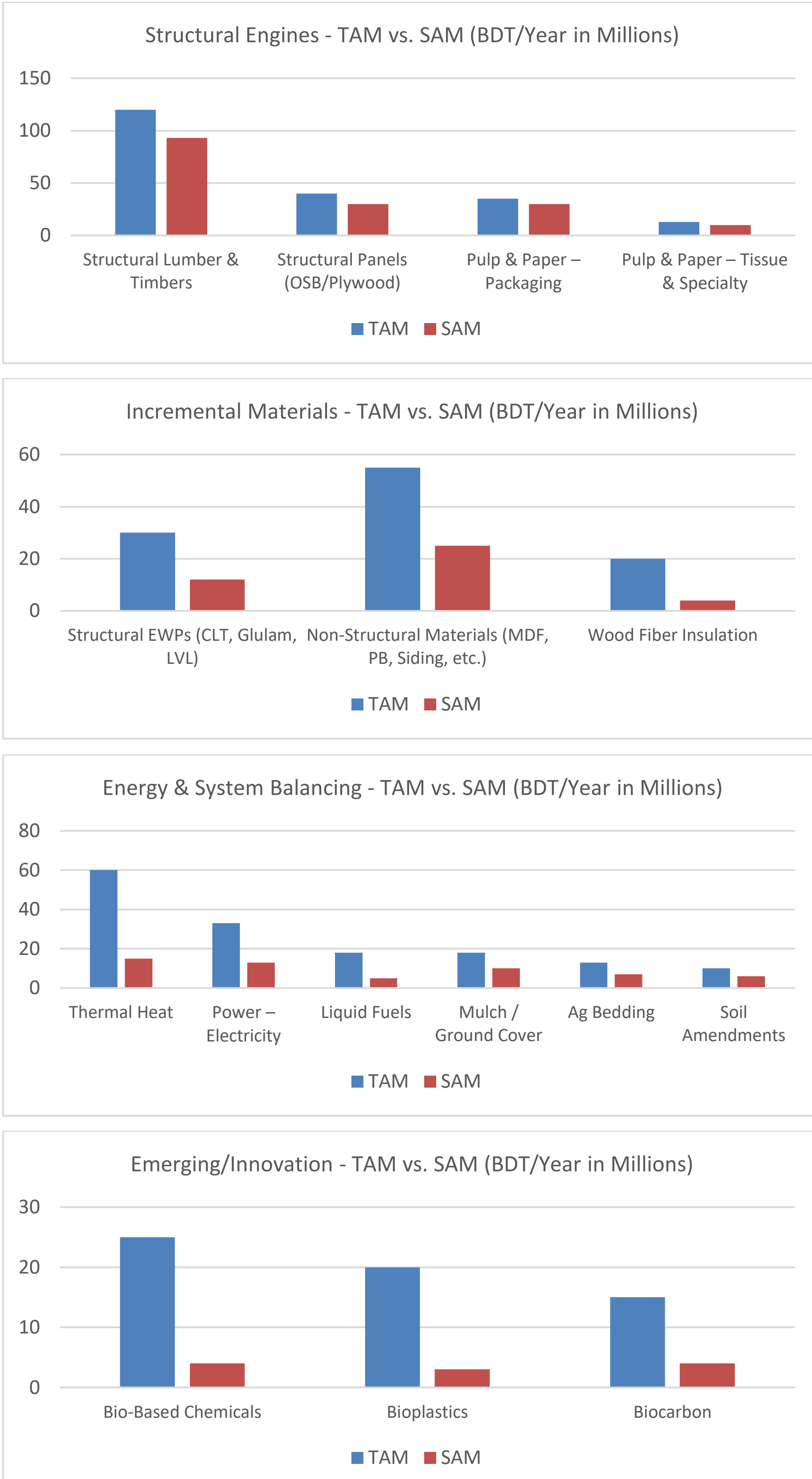
As shown in **Figure 3.4**, Estimates of TAM, SAM, and SOM were developed for major pathway categories to provide context on the scale of demand relative to underutilized fiber volumes.

These market size estimates are intended to illustrate order-of-magnitude differences, not to forecast market capture or project-level performance. In practice, realized utilization is constrained by feedstock availability, operating scale, logistics, and policy conditions, regardless of the size of the theoretical market.

The TAM figures highlight that only a limited number of pathways (primarily those associated with structural wood products, pulp and paper, and energy) operate in markets large enough to absorb substantial volumes of wood fiber. In contrast, many high-value or emerging pathways serve comparatively small markets, even when demand growth prospects are strong.

SAM estimates further narrow this universe by accounting for geographic, regulatory, and logistical constraints, while SOM estimates reflect a conservative view of the portion of each market that could plausibly be supplied by underutilized material. Across all pathways, SOM represents a small fraction of TAM, reinforcing that market size alone is not sufficient to resolve surplus conditions. Viewed alongside Table 3.1, Figure 3.1, and Figure 3.2, the TAM/SAM/SOM analysis underscores why durable utilization solutions depend on a combination of market scale, feedstock alignment, and institutional support rather than on market size alone.

Figure 3.4 – TAM & SAM Estimates



3.9 IMPLICATIONS FOR MARKET & INVESTMENT OPPORTUNITY

Chapter 3's purpose is not to identify a single preferred technology, but to narrow a broad universe of options to a manageable set of pathways that plausibly align with current conditions. The alignment framework provides a disciplined basis for doing so by clarifying which pathways can realistically absorb surplus material at scale; which require policy enablement; and which are better suited to niche or future roles.

Pathways that combine broad feedstock flexibility, meaningful scale potential, and alignment with existing industrial and ownership structures emerge as the most credible candidates for further evaluation. Other pathways remain important for diversification, innovation, and community development, but are unlikely to resolve persistent surplus conditions on their own.

These distinctions inform the selection of pathways carried forward into the following chapter for high-level feasibility analysis. That analysis is intentionally directional rather than definitive. Its purpose is to test order-of-magnitude economics, scale requirements, and key sensitivities, and to identify where further, location-specific due diligence is warranted.

By separating structural alignment from feasibility, the report maintains clarity about what can be concluded at this stage and what remains uncertain. This approach supports more effective decision-making by focusing attention on pathways with the greatest potential for durable impact while preserving flexibility for regional adaptation and future innovation.

3.10 CHAPTER SUMMARY & TRANSITION TO FEASIBILITY ANALYSIS

This chapter used the technology matrix to translate the regional needs assessment into a structured view of market and investment opportunity. Rather than treating underutilized fiber as a single problem with a single solution, the analysis highlights how different pathways align (or do not) with regional conditions and market realities.

The key takeaway is that expanding utilization depends less on the amount of wood available and more on the fit between fiber characteristics, technology requirements, market demand, and operating context. The matrix provides a transparent way to compare these factors and identify where further analysis is justified.

The following chapter applies the alignment framework to a small number of representative pathways to illustrate feasibility considerations, rather than to identify preferred or recommended projects.

CHAPTER 4 – COMPARATIVE ECONOMIC FEASIBILITY & RTL ANALYSIS

4.1 PURPOSE & SCOPE OF THE FEASIBILITY REVIEW

This chapter provides a high-level, comparative assessment of the economic feasibility of selected utilization pathways for small diameter roundwood and mill residuals. Rather than evaluating individual projects or specific facilities, the analysis is intended to assess whether prevailing market values for end products are generally sufficient to support the delivered cost of wood fiber under representative operating assumptions.

To support this objective, the chapter applies a Return-to-Log or Return-to-Fiber (RTL/RTF) framework. RTL/RTF represents the maximum delivered value that a utilization pathway can return to wood fiber after accounting for non-feedstock conversion costs; in other words, the break-even delivered raw material cost. Expressed on a common $/BDT basis across all utilization pathways, this metric provides a consistent means of comparing technologies that differ substantially in scale, technology, product form, and market orientation.

The RTL/RTF analysis is screening-level. It is designed to support relative comparisons across pathways and to illuminate structural differences in economic capacity, rather than to predict prices paid for logs or residuals in any specific location. Capital costs are incorporated through standardized depreciation assumptions, and operating costs reflect typical industry benchmarks. Project-specific factors such as siting conditions, financing structures, ownership models, transportation distances, and firm-level operating efficiencies are not evaluated and can materially affect real-world outcomes.

Consistent with the framework developed in Chapter 3, utilization pathways are interpreted within three broad functional categories:

- *System Anchors*—facilities that operate at scale, absorb large volumes of material, and establish durable market signals for wood fiber;
- *Volume Absorbers*—facilities that utilize meaningful quantities of fiber but whose economic performance is more sensitive to feedstock characteristics, scale, and market conditions; and
- *Policy-Dependent*—technology pathways whose economic viability is contingent on regulatory frameworks, incentives, or avoided-cost structures rather than market values alone.

RTL/RTF results are presented to illustrate how these different pathway types compare in their abilities to support wood fiber utilization under current market conditions. For thermal applications, “revenue” is defined as avoided cost relative to a displaced fuel source on an energy-equivalent basis (e.g. burning biomass in place of propane, etc.). For policy-dependent pathways, indicative RTL/RTF values reflect varying levels of policy support rather than stand-alone market viability.

The intent of this chapter is not to identify preferred technologies or recommend specific investments. Instead, it provides a structured economic lens through which to understand why certain utilization pathways play stabilizing roles in regional wood fiber systems, while others function as complementary or conditional outlets. These insights help inform subsequent discussion of investment readiness, policy design, and strategic deployment of wood utilization solutions.

4.2 RTL/RTF METHODOLOGY & INTERPRETATION

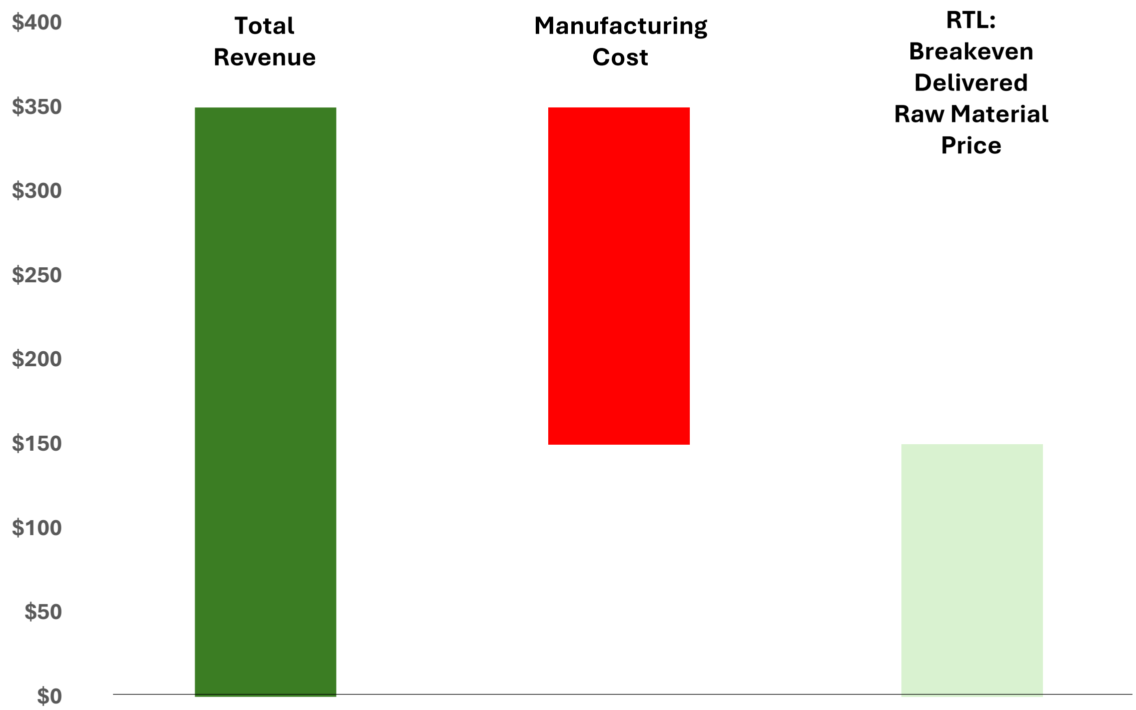
The RTL/RTF metric is used in this chapter as a standardized, screening-level indicator of the economic capacity of different utilization pathways to support wood fiber costs. RTL/RTF is defined as the residual value available to pay for delivered wood fiber after accounting for non-feedstock conversion costs associated with transforming that fiber into a marketable product or energy service.

At a conceptual level, RTL/RTF is calculated as:

RTL/RTF = End Product Revenue minus Non-Feedstock Conversion Cost

Figure 4.1 illustrates the RTL concept graphically, showing how total product revenues minus conversion and operating costs determine the residual value available to the incoming fiber:

Figure 4.1 – Graphic Representation of the RTL Analytical Concept
(*Total Revenue minus Manufacturing Cost equals RTL Value; all values in $/BDT*)



All values are expressed on a bone-dry ton (BDT) basis to enable consistent comparison across pathways that differ substantially in product form, moisture content, density, and yield. For pathways that consume mill residuals or other fiber forms than logs, the term "return-to-fiber" (RTF) is used interchangeably with return-to-log, but the underlying concept is the same.

4.2.1 Interpretation of RTL/RTF Values

RTL/RTF represents the maximum delivered value that a utilization pathway could pay for wood fiber while covering typical operating and capital recovery costs. Higher RTL/RTF values indicate greater economic headroom to support feedstock costs, while lower values indicate tighter margins and greater sensitivity to changes in market conditions, scale, or operating efficiency.

It is important to note that RTL/RTF values should not be interpreted as prices currently paid for logs or residuals, nor as predictions of future market prices. Indeed, if average delivered log/fiber values are not consistently below the RTL/RTF values over time, inadequate allowance for profit and economic risk will offer entrepreneurs and investors little incentive to pursue these businesses.

Actual delivered fiber prices are influenced by many factors not captured in this analysis, including transportation distances, contract structures, ownership integration, competitive dynamics, and local supply/demand imbalances. Instead, RTL/RTF is used here as a comparative metric, allowing relative assessment of the economic role and robustness of different utilization pathways within regional wood fiber systems.

4.2.2 Treatment of Costs & Capital

Non-feedstock conversion costs include operating costs (labor, energy, consumables, maintenance, and overhead) as well as capital costs incorporated through standardized depreciation assumptions. This approach reflects the economic reality that capital investment is required to enable utilization, while avoiding project-specific assumptions related to financing structure, interest rates, tax treatment, or developer-specific risk premiums. Profit margins beyond depreciation are not explicitly modeled; as a result, RTL/RTF values should be viewed as upper-bound indicators of feedstock support capacity under typical conditions.

4.2.3 Treatment of Revenue across Pathways

For manufacturing pathways that produce marketable products (e.g. lumber, panels, pulp, pellets), revenue reflects prevailing or representative FOB mill product values. For thermal energy applications, revenue does not represent product sales, but rather the avoided cost of a displaced fuel (such as propane), expressed on an energy-equivalent basis and adjusted for system efficiency. For policy-dependent pathways, such as biomass-based liquid fuels, revenue reflects a combination of fuel value and assumed policy incentives, and results are therefore presented as indicative ranges rather than market-clearing outcomes.

4.2.4 Appropriate Uses of RTL/RTF Results

Within this study, RTL/RTF is used to:

- Compare the relative economic capacity of utilization pathways
- Distinguish between system anchors, volume absorbers, and policy-dependent options
- Illustrate how scale, market structure, and policy context influence fiber utilization potential

RTL/RTF is not intended to determine project feasibility, select technologies, or establish procurement prices. Rather, it provides a transparent, consistent economic lens for understanding why certain pathways play stabilizing roles in regional wood utilization systems while others function as complementary or conditional outlets.

4.3 CLASSIFICATION OF UTILIZATION PATHWAYS

For the purposes of interpreting RTL/RTF results, utilization pathways are grouped into three functional categories based on their roles within regional wood fiber systems. These categories reflect differences in scale, market structure, and economic behavior, rather than judgments about technological merit or environmental performance.

4.3.1 System Anchor Pathways

System anchor pathways are large-scale, market-mature industries that absorb substantial volumes of wood fiber and establish durable price signals for logs and mill residuals. Examples include commodity lumber, plywood, oriented strand board, and pulp/paper manufacturing. These pathways typically operate at high throughput, are capital-intensive, and rely on well-developed supply chains.

From an RTL/RTF perspective, system anchors tend to exhibit moderate but relatively stable returns to fiber. While their RTL/RTF values are not the highest among all pathways, they are less sensitive to short-term market fluctuations and play a critical role in stabilizing regional fiber markets. As a result, system anchors form the economic backbone of most forest products regions.

4.3.2 Volume Absorber Pathways

Volume absorber pathways include utilization options that can consume meaningful quantities of small diameter roundwood and mill residuals, but whose economic performance is more sensitive to feedstock characteristics, scale, and market conditions. Examples include composite panels (e.g., MDF and particleboard), wood-based insulation products, pellets, and thermal energy applications.

RTL/RTF values for volume absorbers span a wide range. Some pathways may exhibit relatively high RTL/RTF under favorable conditions, while others provide lower but still important economic outlets. In practice, volume absorbers often function as complementary markets, expanding utilization capacity, improving system resilience, and helping manage variability in fiber supply and quality rather than replacing system anchors.

4.3.3 Policy-Dependent Pathways

Policy-dependent pathways are utilization options whose economic viability is contingent on regulatory frameworks, incentives, or avoided-cost structures rather than commodity market prices alone. Biomass-based power generation and liquid fuel production fall into this category. These pathways can deliver important public benefits such as emissions reduction, energy security, and rural economic development, but their ability to support wood fiber costs depends on the availability and durability of policy support.

In RTL/RTF terms, policy-dependent pathways typically show limited or no ability to support feedstock costs in the absence of incentives. When policy support is present, however, they may return positive value to fiber, sometimes at meaningful levels. For this reason, RTL/RTF results for policy-dependent pathways are presented as conditional or indicative outcomes, rather than as stand-alone market signals.

4.3.4 Role of Classification in Interpreting RTL/RTF Results

This classification framework provides important context for interpreting the comparative RTL/RTF results presented in the following section. Higher RTL/RTF values do not necessarily imply greater system importance, nor do lower values indicate lack of relevance. Instead, the categories help explain why different pathways play distinct and complementary roles in regional wood utilization systems, and why a diversified portfolio of utilization options is typically required to address small diameter roundwood and mill residual surpluses effectively.

Table 4.1 presents the utilization pathways selected for quantitative RTL analysis, grouped by their primary market role within the wood fiber system. Grouping pathways in this way reflects the main thesis of this chapter: Utilization outcomes are shaped as much by market role and scale behavior as by technology or product type.

The table is designed to be read horizontally rather than vertically. Each column represents a distinct economic role, ranging from large-scale system anchors that stabilize fiber markets, to volume-absorbing pathways that can reduce localized surpluses under appropriate conditions, to niche or policy-dependent pathways that play more limited or conditional roles. Pathways within a given column are not ranked and should not be interpreted as directly comparable to one another on a project-by-project basis. Instead, the table provides a structured way to frame expectations about relative RTL performance, scale potential, and sensitivity to feedstock cost.

Table 4.1 – Selected Utilization Pathways by Market Role for RTL Analysis

System Anchors	Volume Absorbers	Policy-Dependent Energy
• Commodity sawn lumber • OSB • Plywood • Pulp and paper	• MDF/composite panels • Wood fiber insulation • Wood Wool Cement – Wall Elements • Wood pellets • Biomass thermal energy	• Biomass power generation • Thermochemical conversion to liquid fuels
Notes	**Notes**	**Notes**
• Operate at large scale and are market-sufficient under current conditions • Establish durable price signals for logs and fiber • Directly or indirectly anchor utilization of small diameter roundwood and mill residuals • Provide baseline demand against which other pathways must compete	• Capable of absorbing meaningful volumes of small diameter roundwood and/or mill residuals • Feasibility is sensitive to delivered fiber cost, operating scale, and energy inputs • Include a mix of mill-residual-dominant and SDR-capable pathways • Illustrate the contrast between manufacturing-based utilization and energy-based utilization	• Revenues are closely tied to regulated energy markets and policy incentives • Correctly separated from biomass thermal energy due to fundamentally different economics • Included as contrast cases rather than primary solutions to surplus conditions • Prevent energy pathways from distorting interpretation of market-driven RTL results

4.4 COMPARATIVE RTL RESULTS BY PATHWAY

Table 4.2 presents a comparative summary of indicative RTL/RTF values (labeled in the table as Maximum Delivered Feedstock Value) across the utilization pathways evaluated in this study. Together, the table's rows describe not only the relative economic capacity of each pathway to support delivered wood fiber costs, but also the scale, feedstock requirements, capital intensity, and market maturity that determine each pathway's practical role within regional wood utilization systems. *These results should be interpreted as a system-level comparison of economic capacity and scale, rather than a ranking of preferred technologies.*

Tabe 4.2 – Comparative RTL/RTF Summary Across Utilization Pathways**

Utilization Pathway	Western Lumber	Southern Lumber	Western Plywood	Southern Plywood	OSB	Pulp NBSK (Northern Bleached Softwood Kraft)	Pulp SBSK (Southern Bleached Softwood Kraft)	MDF	Particleboard	Wood Wool Cement-Large Wall Elements	WFI	Wood Pellets Export	Wood Pellets Bagged	Thermal Biomass Small	Thermal Biomass Med.	Thermal Biomass Large	Biomass Cogeneration (CHP)***	Biomass to Liquid Fuel (no subsidy)	Biomass to Liquid Fuel (medium subsidy)	Biomass to Liquid Fuel (high subsidy)
Type	System Anchor	System Anchor	System Anchor	System Anchor	System Anchor	System Anchor	System Anchor	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Volume Absorber	Policy-Dependent	Policy-Dependent	Policy-Dependent	Policy-Dependent
Revenue ($/BDT)	$259	$208	$553	$424	$377	$311	$275	$664	$438	$1,132	$601	$177	$269	$211	$236	$251	$97	n/a	n/a	n/a
Cost ($/BDT)	$123	$122	$305	$244	$289	$165	$158	$527	$355	$996	$440	$137	$185	$107	$78	$50	$58	n/a	n/a	n/a
Maximum Delivered Feedstock Value ($/BDT)	$136	$86	$248	$181	$88	$146	$118	$137	$83	$135	$161	$40	$84	$104	$158	$202	$40	$0	$50	$100
Typical Plant Size (BDT Consumed/Year)	450,000	400,000	250,000	250,000	750,000	1,000,000	900,000	300,000	250,000	20,000	150,000	300,000	100,000	25,000	50,000	100,000	175,000	750,000	750,000	750,000
Indicative Annual Fiber Value/Facility	$59,000,000	$35,000,000	$57,000,000	$43,000,000	$66,000,000	$156,000,000	$115,000,000	$41,000,000	$21,000,000	$3,000,000	$24,000,000	$12,000,000	$8,000,000	$3,000,000	$8,000,000	$20,000,000	$7,000,000	$0	$38,000,000	$75,000,000
Typical Feedstock Type	Logs	Logs	Logs	Logs	Pulpwood/ Small Roundwood	Pulpwood & Mill Residuals	Pulpwood & Mill Residuals	Mill Residual Chips	Mill Residuals (Sawdust/ Shavings)	Pulpwood	Pulpwood & Mill Residual Chips	Pulpwood & Mill Residuals	Mill Residuals (sawdust & shavings)	Mill Residuals & Logging Slash	Mill Residuals & Logging Slash	Mill Residuals & Logging Slash	Mill Residuals & Logging Slash	Pulpwood & Mill Residuals	Pulpwood & Mill Residuals	Pulpwood & Mill Residuals
Capital Intensity*	High	High	High	High	Very High	Very High	Very High	Very High	High	High	High	Medium	Medium	Low	Medium	High	Very High	Very High	Very High	Very High
Market Maturity**	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Mature/ Global	Emerging/ Niche	Emerging/ Niche	Mature/ Policy-Influenced	Mature/ Regional	Mature/ Local	Mature/ Regional	Mature/ Regional	Policy-Driven	Not Market Viable	Policy-Driven	Policy-Driven

*Defined here as: Low = <$50M; Medium = $50–150M; High = $150–400M, Very High = >$400M

**Defined here as: Mature/Global = Established international markets with deep liquidity and transparent pricing; Mature/Regional = Established markets with regional pricing and infrastructure constraints; Mature/Local = Long-standing applications limited by geography and scale; Emerging/Niche = Early-stage or specialized markets with limited deployment; Policy-Driven = Markets dependent on regulatory incentives or avoided-cost structures; Not Market Viable = No positive economic outcome absent policy support.

***For the biomass cogeneration pathway, revenue reflects an assumed wholesale power sales price of approximately $115 per megawatt-hour (MWh). This value is intentionally higher than prevailing market prices for renewable electricity, which are currently estimated to be in the range of $50–$60/MWh. The higher assumed price is intended to represent policy-enabled or contract-based pricing structures, such as long-term power purchase agreements, renewable energy credits, or avoided-cost arrangements that reflect grid reliability, dispatchability, or forest health objectives. This assumption represents a $65–$70/BDT subsidy.

****See Section 4.41 for a brief profile of each pathway included in the table.

4.4.1 Brief Profile of Each Pathway

The following list contains a brief profile of each pathway included in Table 4.2.

- *Western Lumber*—A foundational system anchor that converts sawlogs into commodity lumber while establishing regional log price signals. Western lumber mills are capital-intensive, globally competitive, and indirectly support downstream utilization by generating mill residuals.
- *Southern Lumber*—A high-throughput system anchor optimized for fast-growing southern pine and large, efficient manufacturing complexes. Southern lumber plays a central role in national wood supply chains but is highly sensitive to delivered log cost and housing cycles.
- *Western Plywood*—A mature system anchor producing structural panels from higher-quality veneer logs. Western plywood facilities are capital-intensive, regionally concentrated, and depend on stable access to suitable log diameters and species.
- *Southern Plywood*—A long-established system anchor focused on southern pine veneer production at scale. These facilities provide durable structural products but face increasing competition from OSB and require consistent log supply.
- *OSB*—A dominant system anchor and volume absorber that efficiently utilizes small diameter roundwood at very large scale. OSB plants are among the most capital-intensive wood manufacturing facilities and exert strong influence on regional pulpwood markets.
- *Pulp–NBSK (Northern Bleached Softwood Kraft)*—A global system anchor producing high-value chemical pulp from northern softwood fiber. NBSK mills operate at very large scale, rely on both pulpwood and mill residuals, and are highly sensitive to delivered fiber cost and global pulp markets.
- *Pulp–SBSK (Southern Bleached Softwood Kraft)*—A mature system anchor serving global pulp and paper markets using southern softwood fiber. SBSK facilities provide strong and stable demand for pulpwood and residual chips, but require sustained scale and capital investment.
- *MDF*—A volume absorber that converts mill residuals into composite panels for furniture and interior applications. MDF plants operate at moderate to large scale and help stabilize residual fiber markets but are sensitive to energy and resin costs.
- *Particleboard*—A mature volume absorber utilizing sawdust and shavings to produce low-cost composite panels. Particleboard facilities support efficient residue utilization but offer limited delivered feedstock value relative to other manufacturing pathways.
- *Wood Wool Cement–Large Wall Elements*—An emerging, niche manufacturing pathway producing prefabricated wall elements with high unit value but limited throughput. While attractive from a product-value perspective, these facilities currently have modest system-level impact on regional fiber balances.
- *Wood Fiber Insulation (WFI)*—A growing niche pathway producing insulation products from pulpwood and residual chips. WFI offers higher fiber value than many composite products but remains constrained by market penetration and regional demand.
- *Wood Pellets–Export*—A mature, policy-influenced volume absorber serving international bioenergy markets. Export pellet facilities operate at scale and can absorb significant volumes of low-grade fiber but are exposed to policy shifts and shipping economics.
- *Wood Pellets–Bagged*—A regional volume absorber supplying residential and small commercial heating markets. Bagged pellet facilities operate at smaller scale with higher unit margins, but have limited ability to influence system-wide fiber surpluses.
- *Thermal Biomass–Small*—A local utilization pathway providing space or process heat using mill residuals and slash. These systems are low-capital and effective for site-specific needs but have minimal impact on broader fiber markets.

- *Thermal Biomass–Medium*—A regional volume absorber supplying institutional or industrial heat loads. Medium-scale thermal systems can support local residue utilization but remain constrained by siting, heat demand, and seasonal operation.
- *Thermal Biomass–Large*—A higher-throughput thermal pathway capable of absorbing meaningful fiber volumes where consistent heat demand exists. These systems require careful integration with industrial users to remain economically viable.
- *Biomass Cogeneration (CHP)*—A policy-dependent energy pathway producing combined heat and power from low-value biomass. CHP facilities can absorb substantial fiber volumes but are rarely viable without incentives or guaranteed power offtake.
- *Biomass to Liquid Fuel–No Subsidy*—A pathway that is not currently market-viable due to high capital intensity and low achievable feedstock value. Without policy support, these facilities struggle to compete with conventional fuels.
- *Biomass to Liquid Fuel–Medium Subsidy*—A policy-driven pathway that becomes marginally viable with moderate incentives. Even with support, these facilities face scale, financing, and feedstock cost challenges.
- *Biomass to Liquid Fuel–High Subsidy*—A highly policy-dependent pathway requiring substantial subsidies to operate at scale. While capable of consuming large fiber volumes, deployment is driven by policy objectives rather than underlying market economics.

4.4.2 Reading the Table as a System, Not a Ranking

The RTL/RTF values shown in Table 4.2 represent screening-level estimates of the maximum delivered feedstock value that could be supported by each pathway under representative assumptions. While these values provide an important point of comparison, they should not be interpreted in isolation or as a ranking of preferred technologies. Instead, the table is intended to be read holistically, recognizing that utilization pathways differ fundamentally in their economic function, physical scale, and market context.

Several pathways exhibit relatively high RTL/RTF values but operate at modest facility scale, rely on narrower feedstock specifications, or serve emerging or niche markets. Conversely, system anchor pathways often display more moderate RTL/RTF values but operate at very large scale, absorb diverse feedstock streams, and establish durable regional price signals. Localities with very large or multiple anchor operations can typically utilize an even more diverse feedstock supply (species, log size, etc.). The combination of RTL/RTF and facility scale is therefore critical to understanding system-level impact.

4.4.3 System Anchor Pathways

System anchor pathways—including lumber, plywood, OSB, and pulp—cluster within a relatively narrow range of RTL/RTF values. Despite differences in product form and manufacturing process, these pathways share several defining characteristics: large facility scale, high capital intensity, mature global markets, and consistent demand for wood fiber.

As illustrated by the indicative annual fiber value per facility, system anchors typically support tens to hundreds of millions of dollars per year in feedstock value at a single site. This scale effect explains why system anchors play a dominant role in regional wood utilization systems even when their per-unit RTL/RTF values are not the highest among all pathways. Their importance lies not in maximizing feedstock value per ton, but in providing reliable, high-volume market outlets that stabilize fiber flows and underpin the broader forest products economy.

4.4.4 Volume Absorber Pathways

Volume absorber pathways, including composite panels, wood-based insulation products, pellets, and thermal energy, exhibit a much wider range of RTL/RTF outcomes. Some of these pathways can return comparatively high value to fiber under favorable conditions, while others provide lower but still meaningful outlets for specific feedstock types.

The table highlights that many volume absorbers operate at smaller facility scale than system anchors and often require more narrowly specified feedstocks. As a result, even pathways with attractive RTL/RTF values may deliver relatively modest total annual fiber value on a per-facility basis. In practice, these pathways function as complementary markets, enhancing system flexibility and resilience, improving utilization of mill residuals and lower-quality material, and helping manage variability in supply rather than displacing system anchors.

Thermal biomass pathways illustrate this dynamic with particular clarity. RTL/RTF values increase substantially with system scale, reflecting improved efficiency and lower unit capital costs, yet even large thermal systems remain limited in their ability to absorb regional fiber surpluses relative to manufacturing pathways. Their value lies in localized displacement of high-cost fuels and provision of resilient, place-based utilization options.

4.4.5 Policy-Dependent Pathways

Policy-dependent pathways (including biomass cogeneration and biomass-to-liquid fuels) exhibit RTL/RTF outcomes that are conditional on regulatory frameworks, incentives, or avoided-cost structures. As shown in Table 4.2, these pathways do not support positive delivered feedstock values in the absence of policy support. Under moderate to high policy scenarios, however, they may return meaningful value to fiber, particularly at large facility scale.

The inclusion of representative facility size and indicative annual fiber value highlights the system-wide implications of policy dependence. Large-scale bioenergy or biofuel facilities can consume substantial quantities of biomass, but the resulting feedstock value (and the implied public support required to sustain it) can reach tens of millions of dollars per facility per year. These pathways therefore warrant careful consideration of policy objectives, cost effectiveness, and long-term durability when evaluated as part of a broader utilization strategy.

4.4.6 Implications for Utilization Strategy

Taken together, the RTL/RTF results reinforce that no single utilization pathway can address small diameter roundwood and mill residual surpluses on its own. Effective utilization strategies rely on a portfolio of pathways, each playing a distinct role:

- System anchors provide scale, stability, and durable market signals.
- Volume absorbers expand utilization capacity, improve system flexibility, and capture value from specific feedstock streams.
- Policy-dependent pathways may enable utilization where market-based options fall short, but only under clearly defined and sustained policy frameworks.

This system-level perspective is essential for interpreting RTL/RTF results appropriately and for informing investment, policy, and planning decisions aimed at improving wood fiber utilization outcomes.

4.5 KEY INSIGHTS & IMPLICATIONS FOR WOOD UTILIZATION STRATEGY

The comparative RTL/RTF results presented in Table 4.2 provide several important insights into the structure and behavior of wood utilization systems. When interpreted alongside facility scale, feedstock requirements, capital intensity, and market maturity, these results help explain why certain utilization pathways dominate regional fiber flows, why others play complementary roles, and why some options remain fundamentally policy-dependent.

4.5.1 System Anchors Set the Economic Baseline

System anchor pathways, such as lumber, plywood, OSB, and pulp, form the economic backbone of regional wood utilization systems. Although their RTL/RTF values are generally moderate relative to some higher-value niche pathways, their large facility scale, mature markets, and ability to absorb diverse feedstock streams result in very high total annual fiber value per facility.

This combination of scale and durability allows system anchors to establish stable market signals for wood fiber and to anchor regional supply chains. In practice, the long-term health of wood utilization systems depends less on identifying pathways with the highest per-ton returns and more on maintaining the competitiveness and resilience of these large, high-throughput industries.

4.5.2 Volume Absorbers Expand Utilization but Do Not Replace Anchors

Volume absorber pathways play an essential but distinct role. Composite panels, wood-based insulation, pellets, and thermal applications can utilize material that might be less well suited to system anchor pathways and can, under favorable conditions, return meaningful value to fiber.

However, the analysis demonstrates that many volume absorbers operate at smaller scale, rely on narrower feedstock specifications, or serve markets with limited depth. As a result, even pathways with relatively high RTL/RTF values often contribute a smaller total volume of utilization on a per-facility basis. These pathways are best understood as complements to system anchors. They serve to enhance system flexibility, improve utilization of mill residuals and lower-quality material, and help manage variability in supply; they cannot function as substitutes capable of carrying the system on their own.

4.5.3 Scale & Context Matter as Much as Economics

Across nearly all pathways, facility scale emerges as a critical determinant of both economic performance and system impact. Larger facilities tend to achieve lower unit conversion costs and higher RTL/RTF values, particularly in energy applications, but also require larger, more consistent feedstock supply areas and higher capital investment.

This reinforces the importance of context-specific deployment. Pathways that appear attractive on a per-ton basis may be impractical in regions lacking sufficient feedstock concentration, infrastructure, or market access. Conversely, pathways with modest RTL/RTF values may deliver outsized system benefits where scale, logistics, and market proximity align.

4.5.4 Policy-Dependent Pathways Require Explicit Policy Rationale

The analysis confirms that certain utilization pathways (most notably biomass-based power generation and liquid fuels) do not support positive delivered feedstock values based on market fundamentals alone. Where these pathways show positive RTL/RTF outcomes, those outcomes are directly attributable to policy incentives, avoided-cost frameworks, or regulatory mandates.

Importantly, the large facility scales associated with these pathways imply substantial total annual feedstock value supported per facility, and therefore substantial public or ratepayer contribution where incentives are required. As such, deployment of policy-dependent pathways should be guided by clear public objectives, such as emissions reduction, energy reliability, or wildfire risk mitigation, rather than expectations of market-driven competitiveness.

4.5.5 Implications for Investment & Policy Design

Taken together, these findings underscore that improving utilization of small diameter roundwood and mill residuals is not a question of identifying a single “best” pathway. Instead, it requires a portfolio approach that recognizes the complementary roles of different technologies and markets.

Effective strategies will:

- Maintain and strengthen system anchor industries that provide scale and stability;
- Support selective deployment of volume absorbers to address specific feedstock gaps or regional constraints;
- Apply judicious policy support to enable pathways that deliver public benefits but are not supported by market economics alone; and
- Utilize RTL/RTF analysis to provide a useful framework for evaluating these tradeoffs and for aligning investment and policy decisions with the structural realities of wood utilization systems.

5.1 APPENDIX 1 – COMPREHENSIVE UTILIZATION PATHWAY INVENTORY

Appendix 1, illustrated in **Table 5.1** below, presents a comprehensive inventory of wood fiber utilization pathways considered in this study. Inclusion in this list does not imply feasibility, suitability, or priority in any specific region.

Table 5.1 – Comprehensive Utilization Pathway Inventory

Count	End Use Type	Sub-Category	Examples/Description	Descriptor	Typical Feedstock	Notes
1	Structural	Sawn lumber	Stud/dimension lumber, matting, timbers, fencing, decking	System Anchor	Sawlogs, small logs	Commodity products; mature technology and broad markets; limited new large-scale mill opportunities.
2	Structural	Engineered wood products	Glulam, LVL, LSL, OSL, Parallam	Niche/Specialty	Pulpwood, small logs, large logs (for LVL)	Expanding demand from mass timber construction; good use of small logs and veneers; high capital cost but strong long-term growth potential.
3	Structural	Structural panels	OSB	System Anchor	Pulpwood, small logs	Proven large-scale technology; excellent fiber utilization. Consolidation in industry and high CapEx limit new entrants.
4	Structural	Structural panels	Plywood	System Anchor	Sawlogs	Proven large-scale technology, but long-term loss of market share to OSB.
5	Structural	Mass timber systems	CLT, NLT, DLD, MPP	Niche/Specialty	Dimension lumber	Rapidly growing sector with policy and carbon support; scalable for regional production; aligns with low-carbon building trends.
6	Structural	Roundwood structural products	Poles, pilings, bridge timbers, cabin logs	Niche/Specialty	Medium to large logs	Depends on large or straight logs; niche but high-value markets; strong fit for community or Tribal enterprises where suitable logs exist.
7	Structural	Densified products	Scrimber, Mettlewood	Volume Absorber	Small logs, lumber	Emerging structural composite using small diameter logs; high strength and uniformity; Scrimber is heavy relative to comparable wood products.
8	Structural	Structural wall system	Wood Wool Cement - Large Wall Element	Volume Absorber	Small logs	Emerging product in North America, but needs code approvals; good fit with small log utilization; disruptive to stick-built construction.
9	Appearance	Sawn lumber	Shop, boards, grade hardwood, siding, paneling	Niche/Specialty	Large sawlogs	High-value but log-quality limited; requires large, clear logs; premium niche for specialty hardwoods and softwood clears.
10	Appearance	Veneer	Hardwood and softwood face veneers	Niche/Specialty	Large sawlogs	High-value but log-quality limited; requires large, clear logs; premium niche for specialty hardwoods and softwood clears.
11	Appearance	Non-structural panels	MDF, particleboard, hardboard, decorative plywood	Volume Absorber	Mill residuals	High recovery from mill residuals; mature, consolidated industry; potential for low-formaldehyde or bio-resin innovation.
12	Appearance	Edge-glued; laminated panels	Furniture panels, stair treads, butcher-block, CLT trim	Niche/Specialty	Small logs, sideboards	Small-scale potential using narrow boards, simple mill design; adds value to small-log output; growing demand in furniture and interior finishes.
13	Appearance	Architectural components	Trim, molding, siding, flooring, stair parts	Niche/Specialty	Sawn lumber, veneer	Consistent markets tied to construction activity; competition from imports; value in regional branding and sustainable sourcing.
14	Appearance	Rustic specialty	Rustic furniture poles	Niche/Specialty	Small to medium logs	Good local-enterprise opportunity; low CapEx, high storytelling and aesthetic appeal; supports rural and cultural branding.
15	Appearance	Wood/plastic composites	Decking, cladding, fencing	Volume Absorber	Mill residuals, recycled plastic	Expanding outdoor living and decking markets; uses residuals; stable but resin price-sensitive.
16	Energy	Combustion fuels	Firewood	Niche/Specialty	Small logs, cull logs	Simplest and most direct energy use pathway; widely deployed in rural heating; also markets for bundled firewood for camping, firepits, etc.

17	Energy	Combustion fuels	Boiler fuel, dirty chips	Volume Absorber	Small logs, tops, residuals	Industrial boilers and institutional energy systems. Fuel often cheaper than natural gas, but more operating and maintenance expense.
18	Energy	Densified fuels	Wood pellets, briquettes, torrefied pellets	Volume Absorber	Sawdust, shavings, chips	Enables long-distance transport and use in automated systems, residential heating, and export markets. Production requires drying, milling, and densification; capital-intensive, but offers consistent, high-energy-density product.
19	Energy	Thermochemical conversion	Syngas, pyrolysis oil	Policy-Dependent/Emerging	Small logs, mill residuals	Emerging and versatile pathway converting wood into solid, liquid, and gaseous energy products. Syngas and bio-oil can substitute for fossil fuels or serve as chemical feedstocks, but complex nature of wood makes it difficult to scale to industrial level.
20	Energy	Biochemical conversion	Ethanol, methanol, biogas	Policy-Dependent/Emerging	Mill residuals, pulp liquor	Uses enzymatic or anaerobic digestion processes to convert cellulose and hemicellulose to biofuels. Most mature applications occur in pulp mills or integrated biorefineries; typically reliant on high-moisture or pre-processed biomass streams.
21	Energy	Electric power and/or CHP	Biomass boilers, ORC turbines	Policy-Dependent/Emerging	Tops, bark, fines, chips	Generates renewable electricity and/or process heat from biomass combustion. Combined Heat & Power (CHP) increases efficiency; ideal for co-location with sawmills or campuses. High capital cost and fuel logistics are major challenges but proven at scale.
22	Ag/Horticultural	Animal bedding and absorbents	Shavings, sawdust, pelletized bedding	Volume Absorber	Sawdust, planer shavings, small logs	High-volume, low-value market that provides steady demand for clean, dry residuals. Products must be free of contaminants and consistent in particle size; pelletized bedding is gaining traction for improved handling and absorbency.
23	Ag/Horticultural	Mulch / decorative bark / ground cover	Bark, chips, composted fines	Volume Absorber	Residuals, small logs	Mature and regionally important market serving landscaping, retail, and erosion-control uses. Product value depends on color, texture, and durability. Bark-based mulch often commands a premium over mixed-wood chips.
24	Ag/Horticultural	Soil amendments and biochar	Biochar, compost blends	Policy-Dependent/Emerging	Small logs, bark, residuals	Expanding sector linked to carbon sequestration, soil health, and regenerative agriculture. Biochar adds long-term carbon storage and water-holding benefits, while compost blends improve soil structure and fertility.
25	Ag/Horticultural	Erosion control materials	Wattles, excelsior blankets, Woodstraw	Niche/Specialty	Small logs, chips, veneer	Niche but growing market driven by environmental compliance and wildfire restoration. Wood-based wattles and stakes compete with synthetic materials; biodegradable, natural options increasingly preferred by agencies.
26	Ag/Horticultural	Horticultural media	Wood fiber blends, bark fines	Volume Absorber	Mill residuals (chips), small logs	Substitutes for or complements peat moss and coir in greenhouse and nursery applications. Demand rising as growers seek renewable, locally sourced media with consistent physical and chemical properties.
27	Ag/Horticultural	Agricultural structures	Fence posts, poles, ag/orchard stakes	Volume Absorber	Small logs	Long-established use of small diameter timber, often pressure-treated for durability. Markets stable in rural regions; potential to integrate with thinning or fire risk reduction programs that produce suitable roundwood.
28	Pulp/Paper	Mechanical and chemical pulp	Kraft pulp, TMP, CTMP	System Anchor	Chips, small logs	Not practical for small or remote regions due to high capital cost and scale requirements. Feedstock could be sold to regional mills if nearby (e.g., <100 miles). Heavy foreign competition makes this increasingly difficult to function as a viable anchor industry.
29	Pulp/Paper	Paper products	Paperboard, tissue, newsprint	System Anchor	Pulp fiber	Requires integrated pulp supply. Could be a downstream opportunity only if co-located with an existing pulp mill.

30	Pulp/Paper	Dissolving pulp and derivatives	Rayon, cellophane, CMC	Policy-Dependent/Emerging	Chips, pulpwood	Specialized chemical process with limited domestic base; possible export pulp niche but generally unsuitable for community-scale projects.
31	Pulp/Paper	Fiberboard	MDF, HDF, hardboard	Volume Absorber	Chips, sawdust	Potential synergy with sawmill residuals, but market saturation and competition from imports reduce opportunity.
32	Pulp/Paper	Molded fiber products	Egg cartons, packaging trays	Volume Absorber	Recycled fiber, pulp	Could have regional circular-economy potential if paired with municipal waste fiber streams, but requires forming and drying infrastructure.
33	Environmental/Remediation	Biochar and activated carbon	Soil amendments, filtration media	Policy-Dependent/Emerging	Small logs, residuals	Possible fit for restoration residuals, but expensive relative to mill residuals; Grant-eligible and aligns with carbon, and potentially with wildfire mitigation goals.
34	Environmental/Remediation	Stormwater and filtration media	Engineered wood fiber blends	Niche/Specialty	Residuals	Potential for small-scale enterprises; used in erosion control, urban stormwater BMPs, and bioretention systems; can leverage State/Federal partnerships.
35	Environmental/Remediation	Erosion and habitat restoration materials	Fiber wattles, mulch, compost	Niche/Specialty	Small logs, chips	Potential for small-scale enterprises; used in erosion control, urban stormwater BMPs, and bioretention systems; can leverage State/Federal partnerships.
36	Environmental/Remediation	Carbon sequestration materials	Biochar-concrete, long-life wood	Policy-Dependent/Emerging	Mixed feedstocks	Developing innovation space; could link with local construction markets or pilot carbon-credit projects. Might pair well with engineered-wood demonstration projects.
37	Chemical/Bio-Based	Bio-chemicals	Lignin, tall oil, turpentine, tannins	System Anchor	Pulp liquor, bark	Only viable at large scale or as co-products of existing pulp mills. Does not represent stand-alone opportunities.
38	Chemical/Bio-Based	Bio-chemicals	Extractives, essential oils	Niche/Specialty	Mill residuals	Possible small-scale distillation opportunity (high value/low volume); could target native species (e.g., cedar, pine) for essential oils. Fits cottage or Tribal enterprise model.
39	Chemical/Bio-Based	Bio-oils and biofuels	Pyrolysis oil, SAF, renewable diesel	Policy-Dependent/Emerging	Small logs, residuals	Long-term potential; integration with modular pyrolysis units possible but capital-intensive. Viable as demonstration-scale only if grant-supported.
40	Chemical/Bio-Based	Fermentation products	Ethanol, methanol, biopolymers	Policy-Dependent/Emerging	Sugars from cellulose	Requires advanced pretreatment and biorefinery integration; not feasible for rural-scale projects without external investment.
41	Chemical/Bio-Based	Wood adhesives and binders	Lignin or starch-based resins	Policy-Dependent/Emerging	Extracted biomass	Research or partnership opportunity (e.g., with universities or mass timber producers). Could tie into regional bio-based resin substitution initiatives.
42	Specialty/Cultural	Instrument and carving stock	Maple, walnut, spruce billets	Niche/Specialty	High-grade logs	Supports local artisans, carvers, and luthiers; ideal for Tribal or cultural programs. Niche export potential.
43	Specialty/Cultural	Custom slabs and live-edge furniture	Oversize slabs, tables	Niche/Specialty	Large logs	Excellent branding potential for community enterprises; leverages specialty sawmill capability. Local and online sales possible.
44	Specialty/Cultural	Totem/cultural/artistic poles	Large straight logs	Niche/Specialty	Large logs	Supports Indigenous cultural expression and tourism. Should be supported as a cultural rather than industrial enterprise.
45	Specialty/Cultural	Rustic and artisan products	Peeled poles, crafts	Niche/Specialty	Small/medium logs	Perfect small-wood utilization pathway for low-tech operations. Can supply regional garden, fencing, and rustic furniture markets.
46	Emerging Technologies	Nanocellulose/cellulose nanofibers	Nanofibrillated cellulose, CNC, CNF	Policy-Dependent/Emerging	Pulp, sawdust, chips	High-performance materials, coatings, packaging.
47	Emerging Technologies	Lignin-based carbon fiber and resins	Carbon fiber, resins, biopolymers	Policy-Dependent/Emerging	Kraft lignin, black liquor	Composites, automotive, aerospace.

48	Emerging Technologies	Wood-derived battery materials	Bio-graphite, carbon anodes	Policy-Dependent/Emerging	Chips, pulp	Energy storage, batteries.
49	Emerging Technologies	Wood insulation	Wood insulation	Volume Absorber	Chips	Insulation applications where carbon sequestration is valued; light weight of material likely requires distributed production facilities, but capital intensity requires large scale.
50	Emerging Technologies	Biogenic adhesives and resins	Lignin, soy, tannin-based binders	Niche/Specialty	Extractives, lignin	Plywood, MDF, particleboard adhesives.
51	Emerging Technologies	3D printing with wood composites	Wood flour, CNF, lignin bioinks	Niche/Specialty	Residuals, fines	Additive manufacturing, furniture, design.
52	Emerging Technologies	Hydrothermal carbonization (HTC)	Hydrochar, process water reuse	Policy-Dependent/Emerging	Wet bark, sludge	Soil amendments, carbon materials.
53	Emerging Technologies	Wood-derived hydrogen	Syngas reforming, biomass gasification; electrolysis	Niche/Specialty	Chips, small logs	Green hydrogen fuel; likely market is California, but limited size to date.
54	Emerging Technologies	Wood-derived bioplastics	PLA, PHA, polyols from cellulose/lignin	Policy-Dependent/Emerging	Pulp, extractives	Packaging, biopolymers.
55	Emerging Technologies	Forest-derived nutraceuticals and extractives	Polyphenols, antioxidants, essential oils	Niche/Specialty	Bark, foliage, cones	Cosmetics, pharmaceuticals, health products; likely proprietary technologies.
56	Emerging Technologies	Carbon-sequestering concrete additives	Biochar-cement, carbon-storing concrete	Policy-Dependent/Emerging	Biochar, fines	Construction materials, carbon storage.
57	Emerging Technologies	Cascading biorefinery systems	Sequential extraction of lignin, sugars, oils	Policy-Dependent/Emerging	Mixed residuals	Multi-product bioeconomy hubs.
58	Emerging Technologies	Acetylated, furfurylated, thermally modified wood	Dimensionally stable, durable wood	Niche/Specialty	Sawn lumber	Decking, cladding, exterior joinery; relatively low capital cost, but limited market traction to date.
59	Emerging Technologies	Torrefaction + biochemical integration	Torrefied fuel + bioproduct extraction	Policy-Dependent/Emerging	Small logs, bark, chips	Energy, biochemicals.
60	Emerging Technologies	Cross-laminated bamboo / hybrid mass timber	Hybrid bamboo/wood mass timber	Niche/Specialty	Small logs, bamboo, veneers	Structural panels, architecture.

5.2 APPENDIX 2 – TECHNOLOGY & PATHWAY ALIGNMENT MATRIX

Appendix 2, shown below as **Table 5.2**, serves as a structured database used to generate the analytical figures and insights presented in Chapter 3.

Table 5.2 – Technology & Pathway Alignment Matrix

Evaluation Criteria	Main Market	Submarkets	Tier	Group Overview & Role in Fiber Utilization	TAM/SAM/SOM	Feedstock Fit & Volume Needs	Cost & Market Competitiveness	Geographic Alignment	Policy & Regulatory	Financial Characteristics	Key Risks & Sensitivities
What it is	**The broad end-use category where wood fiber ultimately goes (e.g., energy, structural materials, appearance products).**	**This column is a more specific product or application within the main market (e.g. thermal energy vs. liquid fuels, OSB vs. plywood).**	**A simple ranking of maturity, readiness, or relevance (Tier 1 = established, Tier 2 = emerging, Tier 3 = early-stage or niche).**	**A description of what the pathway does and how it contributes to using wood fiber.**	**A high-level indication of Total Addressable Market, Serviceable Available Market, and Serviceable Obtainable Market.**	**How well different types of wood fiber (mill residuals, small diameter roundwood, clean chips, bark, fines, etc.) match the pathway, and how much volume is typically required.**	**An assessment of whether products from this pathway can be produced at costs that allow them to compete with alternatives in the market.**	**How dependent the pathway is on being located near specific resources, infrastructure, labor pools, or end markets.**	**The degree to which the pathway depends on incentives, mandates, carbon policy, permitting conditions, or regulatory support.**	**The general financial profile of the pathway, including capital intensity, operating risk, revenue stability, and typical return profile.**	**The main factors that could cause the pathway to underperform or fail (e.g. feedstock prices, market volatility, policy changes, technology risk).**
How to interpret	**This column describes the big-picture role the pathway plays in the forest products economy and where it fits relative to other major outlets for fiber.**	**This column helps distinguish pathways that might look similar at a high level but differ significantly in scale, economics, and feasibility.**	**Lower tiers generally indicate more proven pathways with existing infrastructure, while higher tiers suggest greater uncertainty or development risk.**	**Read this first to quickly understand why this pathway exists and what problem it does—or does not—help solve in the utilization system.**	**This column signals scale potential, not guaranteed demand. Large markets are attractive, but only if other columns also align. Also, TAM = demand-side ceiling SAM = supply-constrained reality SOM = what actually gets built**	**Strong alignment means the pathway can readily use locally available material without excessive sorting, preprocessing, or scale pressure.**	**This column answers the question: "Can this work economically without heroic assumptions?" Pay attention to sensitivity to feedstock cost, transportation, scale, and capital intensity.**	**Highly location-specific pathways only work in certain regions; broadly aligned pathways can work across many geographies if other conditions are met.**	**Pathways that rely heavily on policy may be viable today but exposed to political or regulatory change over time.**	**This information helps distinguish capital-heavy, long-payback investments from simpler, lower-risk opportunities, even if both are technically feasible.**	**Use this column to understand what must go right for the pathway to succeed and where downside risk is concentrated.**
	Energy	Thermal	1	A direct and practical use for mill residuals and some small diameter wood, typically used on site or nearby to provide heat and reduce fossil fuel use.	TAM = 50 to 70 million BDT/year; SAM = 10 to 20 million BDT/year; and SOM = 50,000 to 200,000 BDT/year per site	Works well with bark, mixed residuals, and other low-grade mill residual streams, and can also use chipped small diameter roundwood; volumes are moderate and local, but SDR typically costs more due to harvesting and chipping.	Often the lowest-cost energy outlet when there are nearby heat users and low-cost residuals. It can beat fossil heat on a delivered $/MMBtu basis only when fuel handling and hauling are minimal; economics drop quickly with longer distance or higher processing needs.	Best fit when the fuel and the heat user are co-located or very close, because hauling bulky, low-value material gets expensive quickly. Works especially well where there is a steady local heat load (mills, schools, hospitals, greenhouses).	Often shaped by local air-quality permitting and boiler emissions rules; incentives for renewable heat or carbon reductions can improve economics but are not always required.	Usually modest-to-moderate CapEx with economics driven by displacing expensive fuels (propane/diesel/natural gas) and achieving high uptime.	Sensitive to heat load consistency, fuel moisture/handling costs, maintenance reliability, availability of low-cost alternate fuels (e.g, natural gas) and changes in air permitting requirements.
	Energy	Power	2	A limited-use market for mill residuals that can work in certain locations or situations, but is often held back by high fuel costs, expensive facilities, and reliance on policy support; using small diameter roundwood typically makes fuel costs even higher.	TAM = 30 to 35 million BDT/year; SAM = 10–15 million BDT/year; and SOM = 30,000 to 1,000,000 BDT/year per facility	Can use large, steady volumes of bark, mixed residuals, or clean chips, and can also use chipped SDR, but the higher cost of collecting and sizing SDR often makes it uneconomic except in site-specific situations.	Typically hard to compete on cost against grid power (especially low-cost natural gas/renewables) without strong incentives. It can pencil in niche situations (high local power prices, firm capacity value, on-site load), but margins are very sensitive to feedstock cost and capital costs as they relate to plant scale.	Highly location-specific: needs a large, reliable fiber supply within an economical haul radius, plus grid access and permitting feasibility at the site. Generally only works where fuel logistics and infrastructure are already favorable.	Frequently depends on renewable power policies (RPS/REC markets), interconnection rules, and stringent air permitting; policy support often determines viability.	Typically high CapEx and thin margins, requiring long-term contracts (PPA) and very disciplined fuel procurement to pencil out.	Exposed to policy shifts, power price volatility, interconnection delays, feedstock price escalation, and downtime/availability risk.

	Energy	Liquid	3	A long-term and mostly experimental use of wood fiber that requires complex and costly processing; not a realistic outlet for mill residuals or small diameter wood today.	TAM = 15 to 20 million BDT/year; SAM = 4 to 6 million BDT/year; and SOM = 10,000 to 500,000 BDT/year per site	Can use clean, segregated chips or sawdust from mills, but requires very large and steady volumes; SDR must be chipped and dried, which adds cost, and most other residual streams are a poor fit.	Usually not cost-competitive today without significant policy support and very large scale. Costs are driven by capital intensity, preprocessing, and conversion yields, so viability depends on premium pricing (e.g. low-carbon credits) and a steady supply of clean, low-cost fiber.	Location-specific to places that can support very large scale and complex logistics (transportation hubs, existing fuel infrastructure, strong distribution). Often depends on being near both feedstock aggregation and the policy-supported fuel markets that drive demand.	Strongly influenced by low-carbon fuel programs and renewable fuel standards; permitting can be complex, but policy credit value is usually the make-or-break factor.	Very capital-intensive with scale requirements and long development timelines; economics often depend on credit markets plus stable offtake contracts.	High sensitivity to policy/credit values, technology scale-up risk, hydrogen/energy inputs, feedstock logistics, and financing availability.
	Building Materials - non-structural	Siding, decking, paneling, flooring, non-structural panels	2	Manufactured interior products and appearance-oriented panels that use refined fibers from mill residuals or small diameter wood, but only where suitable plants and processing infrastructure already exist.	TAM = 40 to 65 million BDT/year; SAM = 20 to 30 million BDT/year; and SOM = 50,000 to 1.5 million BDT/year per site	Well suited to refined fibers produced from clean mill residuals or processed SDR, though SDR requires additional size reduction and drying, adding cost; volumes are tied to existing PB and MDF mill capacity.	Can be competitive when making consistent, quality products with manageable processing costs and access to steady demand. Pricing is often attractive, but competitiveness depends on drying/finishing costs and whether pricing can beat alternative materials and imported products after freight.	Siding/decking/flooring and other appearance-grade wood products: generally broad geographic fit because products can ship, but competitiveness improves with proximity to fiber supply, labor, and distribution channels. Works best where there is an existing secondary wood-products cluster or strong building materials logistics. PB: location-specific to regions with established furniture/cabinetry and interior products manufacturing, plus steady supplies of suitable residuals. Fiber must be hauled to fixed facilities, so PB works best where residuals and markets are both nearby. MDF: Similar to PB but often even more cluster-dependent: best near large, consistent residual streams and major interior product manufacturing hubs. Less suited to remote regions due to freight costs for both fiber and finished product.	Generally governed by building codes, product standards, and (in some areas) fire/WUI requirements; treated products may face additional compliance requirements.	Moderate CapEx with value-add potential; profitability often depends on branding, distribution, and finishing rather than pure commodity scale.	Tied to housing/remodel cycles, competition from composites/PVC/imports, quality consistency, and freight to target markets.

	Building Materials - Non-structural	Wood Fiber Insulation (Rigid Panels; Batt & Loose-Fill variants)	2	A non-structural building material that provides thermal, acoustic, and moisture-management performance using wood fiber rather than fossil-based insulation. Creates a higher-value outlet for clean residuals than mulch or bedding, but does not absorb low-grade or bark-heavy material.	TAM = 15 to 20 million BDT/year; SAM = 2 to 5 million BDT/year; and SOM = 50,000 to 150,000 BDT/year per site	Requires clean raw material—mainly chips, but small amounts of sawdust and/or planer shavings can also be included with tight quality control; bark, dirt, and mixed residuals are generally unsuitable. Volume requirements are moderate relative to structural panels, but consistent raw material quality is critical.	Typically not cost-competitive with fiberglass or foam insulation on a pure $/R-value basis. Competitiveness improves where energy costs are low, clean residuals are inexpensive, and buyers value carbon, moisture performance, and indoor air quality attributes.	Moderately location-specific: benefits from proximity to clean residual supply and reliable energy infrastructure, but finished products can ship regionally. Strongest fit near markets with progressive building codes and demand for high performance building envelopes.	Driven mainly by building energy codes and embodied-carbon policy, plus product testing/standards and certifications recognized by builders/inspectors.	Capital- and energy-intensive manufacturing; performance depends on premium pricing and steady demand in high-performance building segments.	Sensitive to market adoption/education, energy prices, freight, and the availability/cost of clean furnish; slower uptake if codes/certifications lag.
	Building Materials – Structural	Lumber/Timbers	2	Markets that mainly rely on larger logs and only affect mill residual volumes indirectly, with limited direct use of small diameter roundwood.	TAM = 110 to 130 million BDT/year; SAM = 85 to 100 million BDT/year; and SOM = 400,000 to 1 million BDT/year per site	Primarily relies on larger diameter logs; SDR can be used for limited products but often yields lower recovery and higher costs, while residuals are generated rather than consumed.	Competitive when sawlog-quality material is available at a delivered cost that supports lumber prices, but it struggles if the log mix is small/low-grade or haul costs are high. Profitability is tightly linked to log cost, recovery/yield, and lumber market cycles.	Strongest where there is consistent sawlog supply, logging capacity, and established sawmilling infrastructure. Location is primarily driven by where suitable logs are available and can be delivered at competitive cost.	Influenced by building code requirements, trade/tariffs, phytosanitary rules, and forest policy that affects log supply and operating conditions.	Often commodity-cyclical; margins swing with log costs, lumber prices, and mill utilization/uptime.	Highly sensitive to housing starts, log availability and delivered log cost, labor constraints, and trade/price volatility.
	Building Materials - Structural	EWP (LVL, Parallam, CLT, Glulam, etc.)	2	Products that can incorporate small diameter wood or residual-based inputs in some cases, but only after significant processing and where scale and cost requirements can be met.	TAM = 25 to 35 million BDT/year; SAM = 8 to 15 million BDT/year; and SOM = 50,000 to 300,000 BDT/year per site	Can use small diameter logs and clean chips or strands made from SDR, but requires consistent quality and large volumes; SDR typically needs preprocessing that raises delivered cost.	Can be competitive for high-value engineered products, but costs are sensitive to fiber quality, drying/adhesive costs, and capital intensity. Works best with secure, consistent, on-spec inputs and selling into stable, higher-margin markets that can absorb manufacturing and certification costs.	Typically aligned with regions that already have structural lumber production, skilled labor, and construction demand, since EWP plants depend on stable input supply and tight quality control. Products can ship, but siting near upstream supply chains improves cost and reliability.	Relies on code acceptance, product certification, and approvals (especially for mass timber); procurement standards can accelerate adoption.	Higher CapEx than commodity lumber with economics tied to throughput, quality control, and stable project/developer demand.	Exposed to market adoption pace, adhesive/resin costs and supply, input lumber quality/price, and project-cycle volatility.

	Building Materials - Structural	Panels	2	Manufactured products that can use chips or strands made from small diameter wood and residuals, but only where suitable plants and regional manufacturing capacity already exist.	TAM = 35 to 45 million BDT/year; SAM = 25 to 35 million BDT/year; and SOM = 600,000 to 1,200,000 BDT/year per site	Well suited to clean chips, strands, or flakes produced from mill residuals or SDR, though SDR must be reduced in size first, adding cost; volumes are tied to existing panel mill capacity.	Highly cost-competitive at large scale in established regions, but tough to enter new areas due to capital intensity and strong incumbents. Likely an opportunity to develop a large-scale OSB plant in the western US, especially to serve the large California market. Delivered fiber cost, resin/energy costs, and freight to big construction markets largely determine whether a mill can win on price.	Most panel mills are large fixed facilities that require a deep, steady fiber basket and strong truck/rail access. They tend to be viable only in regions with high fiber density and established industrial logistics; long inbound haul distances quickly undermine economics.	Governed by building code standards, and often formaldehyde/emissions regulations and permitting for large industrial facilities; trade policies can matter.	Very capital-intensive and scale-driven; profitability hinges on fiber cost, resin/energy inputs, and running near full utilization.	Sensitive to housing cycles, resin prices, fiber cost/availability, and logistics; high downside if operating rates drop.
	Pulp/Paper	Pulp	1	A core market that has long used mill residuals and small diameter wood, capable of absorbing large and steady volumes where pulp mills are operating.	TAM = 45 to 55 million BDT/year; SAM = 35 to 45 million BDT/year; and SOM = 800,000 to 1,500,000 BDT/year per site	Strong fit for clean chips from mill residuals and chipped SDR, with very large and continuous volume needs; SDR has higher harvesting and chipping costs, while residual chips are often less uniform, which pulp mills prefer to avoid because it can reduce digestion efficiency.	Often competitive where there is low-cost pulpwood and strong mill scale, but margins are commodity-like and exposed to global cycles. High delivered fiber cost or long haul distances quickly erode competitiveness versus other regions and imports.	Very location-specific to regions with existing mills, infrastructure, and large fiber baskets, since facilities are capital-intensive and cannot move. Fiber must be delivered to the mill, so the surrounding supply radius is a primary constraint.	Heavily regulated for air, water, and effluent, with significant permitting and compliance requirements; decarbonization policy may affect energy systems.	Extremely capital-intensive with large fixed costs; economics depend on global pulp prices, energy costs, and sustained high operating rates.	High exposure to commodity price swings, energy costs, environmental compliance costs, and long-cycle capital risk.
	Pulp/Paper	Packaging	1	A major outlet for mill residuals and small diameter wood that turns fiber into high-volume packaging products, closely tied to existing mill infrastructure.	TAM = 30 to 40 million BDT/year; SAM = 25 to 35 million BDT/year; and SOM = 800,000 to 1,500,000 BDT/year per site	Uses large volumes of clean chips from mill residuals and chipped SDR, with broad tolerance for species mix; SDR generally has higher harvesting and size-reduction costs, while residual chips are often less uniform in size, which can modestly reduce pulping efficiency but is usually manageable in packaging grades.	Generally more resilient than many paper grades, but still very scale- and cost-driven. Competitiveness hinges on low-cost fiber, energy efficiency, logistics to major consumer/industrial corridors, and the ability to compete with recycled fiber where it is cheaper.	Closely tied to regions with operating packaging/paper assets and robust fiber procurement networks. New or expanded capacity generally works best where the industrial base and inbound fiber logistics already exist.	Affected by recycling rules, EPR policies, and restrictions on plastics, which can support demand but vary widely by jurisdiction.	Capital-intensive but can have more stable demand than some commodity products; profitability depends on fiber furnish costs and mill scale.	Sensitive to recovered fiber prices/quality (if recycled), energy costs, freight, and shifts in consumer packaging formats.
	Pulp/Paper	Tissue/Specialty	2	More selective pulp and paper markets that can use residuals in some cases, but have tighter specifications and more limited flexibility than packaging grades.	TAM = 10 to 15 million BDT/year; SAM = 8 to 12 million BDT/year; and SOM = 300,000 to 800,000 BDT/year per site	Can use clean, well-controlled residual-derived chips and limited SDR, but requires tighter control over chip size, cleanliness, and fiber quality; variability in residual chip size and the added processing cost of SDR both limit usable volumes.	Can support higher pricing than commodity paper, but production costs are also higher (quality control, furnish requirements, converting). Competitive position depends on access to suitable fiber, strong customer relationships, and avoiding high freight into established specialty market clusters.	Geographically constrained because it relies on specialized equipment, consistent furnish quality, and established supply chains. Best fit in regions with existing tissue/specialty manufacturing clusters and supporting logistics.	Governed by product standards and hygiene/food-contact requirements where relevant; less policy-driven than fuels but still compliance-heavy.	Capital-intensive with relatively steady demand; margins depend on energy efficiency and pulp/fiber input costs.	Sensitive to energy and pulp price changes, supply chain disruptions, and competitive capacity expansions.

	Ag/Horticulture	Mulch	1	A straightforward local market that can directly use mixed mill residuals and low-grade small diameter wood with minimal processing.	TAM = 15 to 20 million BDT/year; SAM = 8 to 12 million BDT/year; and SOM = 50,000 to 300,000 BDT/year per site	Uses bark, coarse residuals, and chipped SDR directly, with flexible specifications; SDR must still be harvested and sized, which raises costs compared to mill residuals.	Often competitive because it can use lower-value bark and mixed mill residuals that are less suitable for higher-value products; the end product can tolerate variability. However, it is a bulky, freight-heavy product; delivered cost to local markets and competition from nearby suppliers are the main determinants.	Mostly local/regional because it is bulky and freight-heavy; delivered cost is dominated by trucking. Best fit near population centers and landscaping demand, with nearby bark/residual supply.	Generally light, with some local rules around dyes, contaminants, and handling of yard/green waste if blended; siting/permitting can matter for grinders.	Low-to-moderate CapEx and often seasonal; profits depend on local delivered cost and access to steady bark/residual supply.	Dominated by freight costs, seasonality, local competition, and feedstock contamination/consistency.
	Ag/Horticulture	Bedding	1	A practical and nearby outlet for clean mill residuals and small diameter material, typically serving regional agricultural users.	TAM = 10 to 15 million BDT/year; SAM = 5 to 8 million BDT/year; and SOM = 50,000 to 250,000 BDT/year per site	Uses clean, dry sawdust or shavings from mills in steady but moderate volumes; SDR can be used only after processing into suitable forms, which adds cost.	Typically competitive in regions with concentrated poultry and other livestock operations and reliable low-cost residual supply (especially clean shavings). Economics weaken if one must make shavings from roundwood or ship long distances, since freight and processing dominate.	Regional/local market: strongest where there are concentrated poultry and other livestock operations and nearby sources of clean shavings/sawdust. Shipping longer distances is possible, but it quickly becomes a freight-driven business.	Generally light, but can be influenced by biosecurity expectations, dust/quality specs, and disposal/land-application rules for used bedding/litter.	Typically low CapEx, but margins are freight-driven and depend on access to low-cost clean shavings and steady buyers.	Sensitive to competition for clean shavings (pellets/panels), poultry/livestock cycles, moisture/quality specs, and transport costs.
	Ag/Horticulture	Soil Amendments	1	Markets that can accept a wide range of residual-based materials for soil improvement, with high tolerance for variability and mostly local demand.	TAM = 8 to 12 million BDT/year; SAM = 4 to 7 million BDT/year; and SOM = 50,000 to 200,000 BDT/year per site	Can use a wide range of residual streams and chipped SDR, including fines and bark, with flexible volume needs; SDR economics depend on local harvesting and processing costs.	Can be competitive when tied to local composting/blending systems and when the product can command a premium (organic/soil health). Costs are sensitive to contamination control, processing/curing time, and the ability to compete with cheaper compost, manure, or peat substitutes.	Best fit where wood can be co-located with other organics (manure, green waste, food waste) and where end users are nearby. Viability is strongly influenced by siting/permitting and the economics of moving bulky material.	Often governed by composting and organics regulations (siting, odor, runoff, pathogen testing), and labeling rules for soil products.	Moderate CapEx with economics tied to tipping fees (if any), blending inputs, and local market development; bulky product limits radius.	Sensitive to permitting/neighbor issues, contamination (plastics/metals), odor management, and local demand/pricing.
	Chemical/Bio-Based	Bio-chemicals	3	Early-stage markets that would use wood fiber indirectly and are currently too expensive and immature to serve as meaningful outlets for mill residuals or small diameter wood.	TAM = 20 to 30 million BDT/year; SAM = 2 to 5 million BDT/year; and SOM = 50,000 to 200,000 BDT/year per site	Requires highly uniform, processed intermediates; both mill residuals and SDR must undergo extensive preprocessing, making direct use uncommon and costly.	Usually not cost-competitive at small scale; economics depend on high-value products, very consistent feedstocks, and strong offtake contracts. Capital intensity and technology risk mean competitiveness often requires incentives, carbon premiums, or strategic buyers.	Currently concentrated near refining/chemical infrastructure and large industrial hubs, not forest regions. Wood-based supply chains can work, but only where feedstock aggregation and industrial siting constraints align.	Strongly shaped by chemical regulations and permitting, plus incentives for low-carbon industrial products; market access may depend on certification/claims rules.	Typically very capital-intensive with long development timelines; requires high utilization and reliable offtake to finance and operate.	High risk from technology scale-up, product qualification timelines, price competition with petrochemicals, and policy/incentive uncertainty.
	Chemical/Bio-Based	Bioplastics	3	Speculative, long-term markets that depend on advanced processing and are not positioned today to use significant amounts of mill residuals or small diameter wood.	TAM =15 to 25 million BDT/year; SAM = 1 to 4 million BDT/year; and SOM = 50,000 to 250,000 BDT/year per site	Depends on refined wood-derived intermediates produced at large scale; neither segregated mill residuals nor SDR are typically suitable without multiple, costly conversion steps.	Generally not cost-competitive with conventional plastics without policy support or price premiums. Costs depend on conversion pathway, yields, and scale, so competitiveness typically requires large plants, reliable low-cost feedstock, and strong demand for "bio-based" claims.	Typically located near major petrochemical/biochemical manufacturing clusters and downstream converters, rather than near timber supply. Geographic fit depends more on industrial integration and logistics than proximity to forests.	Influenced by rules on compostability/labeling standards, plastic bans, and procurement policies; regulatory definitions can materially affect demand.	High CapEx and commercialization risk; economics often require premium markets or policy tailwinds, not pure cost parity.	Sensitive to performance vs incumbents, certification/claims scrutiny, feedstock and additive costs, and demand adoption rates.

	Chemical/Bio-Based	Biocarbon	2	A niche, higher-value market where wood fiber is converted into engineered biocarbon products (such as filtration media or adsorbents), with limited but growing demand tied to performance specifications rather than bulk volume.	TAM =10 to 20 million BDT/year; SAM = 2 to 6 million BDT/year; and SOM = 50,000 to 300,000 BDT/year per site	Can use clean mill residuals or chipped small diameter roundwood as inputs, but requires controlled processing to produce consistent biocarbon; SDR adds cost due to harvesting and size reduction, and total volumes are modest relative to other markets.	Can be competitive in certain markets because biocarbon can replace fossil-based carbon with a performance or carbon benefit. Economics hinge on conversion efficiency, energy integration, and whether customers pay a premium (or carbon policy recognizes the value).	Moderately flexible because the product can ship, but siting still benefits from being near low-cost feedstock and efficient transport. Geographic fit is often driven more by proximity to end markets (steel, filtration, soil, specialty industrial) than by forest location alone.	Often supported by industrial decarbonization policy and carbon accounting, but still subject to air permitting and emissions compliance at production sites.	Moderate-to-high CapEx with returns driven by securing spec-compliant offtake (steel/metals, filtration, specialty uses) and consistent operations.	Sensitive to offtake certainty, product specs/consistency, carbon credit value (if used), energy costs, and permitting/siting constraints.