Economic and Community Contributions of the Forest Product Industry in Colorado

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Abstract

Active forest management is necessary and beneficial in various perspectives. For example, the forest product industry can utilize harvested trees, turn them into value-added products, and cover the cost of forest management. The purpose of this report is to enhance understanding by the public, state legislators, and stakeholders of economic and community contributions of the forest product industry in Colorado. In addition, the report assesses the economic impact of public grants to this industry in terms of creating economic activities in Colorado's state economy. The current state of the forest product industry is depicted through industry statistics from the U.S. Bureau of Economic Analysis (BEA) and the U.S. Census Bureau. This summary is followed by a detailed economic impact analysis of the United States Department of Agriculture (USDA) Wood Innovation Program Grants and an economic contribution analysis that illustrates how exports of this industry can expand economic activities in other industries and at different geographies. The report concludes with a qualitative illustration of additional agricultural and ecological contributions and a discussion of present and emerging trends with new technologies to complement the formal economic analysis and highlight additional contributions.

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1. Introduction

Regardless of where they live, Coloradoans, like all Americans, rely on forest products every day. Broadly defined, a forest product is made from materials derived from the practice of forestry – the management of treed ecosystems. These products can be obvious, such as paper, pencils, and dimensional lumber. However, there are thousands of overlooked items made from forest products that may be used without even noticing where they come from. Some examples are chocolate, coffee, rubber, cork, and the cellulose that makes its way into countless consumer products.

The active management of Colorado forests provides significant economic and ecological benefits. The value of these benefits may not be obvious – much like the individual products forests provide. Actively managing Colorado forests can:

- create local jobs and support the local economy
- reduce the likelihood and severity of wildfires
- protect water resources and water quality
- foster carbon neutral (or even carbon negative) energy independence
- create diverse wildlife habitats
- increase forest resilience to severe insect or disease events
- increase recreational opportunities

However, the past practice of forest management in Colorado may have been biased by the misconception that any form of wildfire, whether naturally occurring or human-caused, should be suppressed due to the fear created by past uncontrollable fires. While it is now accepted that fire is a natural part of forests, there are millions of acres of abnormally dense forests with lower biodiversity, less protection from insects and disease, and ironically higher risk of catastrophic fires in Colorado. In terms of treating these dense forest areas with appropriate management, the forest product industry comes out to be an effective way to make revenues by selling value-added products and cover the cost of active management of thinning forests.

The purpose of this report is to compile both qualitative and quantitative information on the economic and ecological contributions forest product companies in Colorado provide to the communities in which they operate and to inform the public and state legislators. The report includes an assessment of the economic impact of public funding through federal programs on the Colorado state economy. Chapter 2 examines the current state of the forest product industry in Colorado by using statistical data from governmental agencies such as Bureau of Economic Analysis (BEA) and the Census Bureau. Chapter 3 presents the result of economic impact analysis of the 2024 Wood Innovation Program

Grants from USDA Forest Services. Chapter 4 accounts for economic contribution analysis of the forest product industry in Colorado. Chapter 5 articulates a qualitative aspect of the contribution of the forest product industry in terms of agriculture and ecology. Chapter 6 illustrates the present and emerging trends in the forest product industry based on the businesses in Colorado that were contacted for the purpose of this study.

2. Colorado's Forest Product Industry

In this chapter, data relevant to Colorado's forest product industry sectors from the U.S. Bureau of Economic Analysis (BEA) and the U.S. Census Bureau are collected and analyzed to examine historical trends and the current state of the industry. The forest product industry sectors are (113) forestry and logging, (115) support activities for agriculture and forestry, (321) wood product manufacturing, and (337) furniture and related-product manufacturing under 3-digit NAICS codes. The choice of codes was based on consultation with Timothy Reader from Colorado State Forest Service to determine those codes most relevant to Colorado. The forest product industry is an umbrella term for these four industry sectors. The selection of industry sectors is limited by the available sector classification from the data sources.

(113) forestry and logging includes (1131) timber tract operations, (1132) forest nurseries and gathering of forest products, and (1133) logging. (115) support activities for agriculture and forestry includes (1151) support activities for crop production, (1152) support activities for animal production, and (1153) support activities for forestry. (321) wood product manufacturing includes (3211) sawmills and wood preservation, (3212) veneer, plywood, and engineered wood product manufacturing, and (3219) other wood product manufacturing such as millwork, wood container and pallet manufacturing, manufactured home manufacturing, prefabricated wood building manufacturing, and all other miscellaneous wood product manufacturing. (337) furniture and related product manufacturing includes (3371) household and institutional furniture and kitchen cabinet manufacturing, (3372) office furniture manufacturing, and (3379) other furniture related product manufacturing such as mattress manufacturing and blind and shade manufacturing.

2.1 Real GDP, Compensation of Employees, and Employment from BEA

Figure 1. Real GDP by industry in Colorado (millions of chained 2017 dollars)

(Source: BEA real GDP by industry)

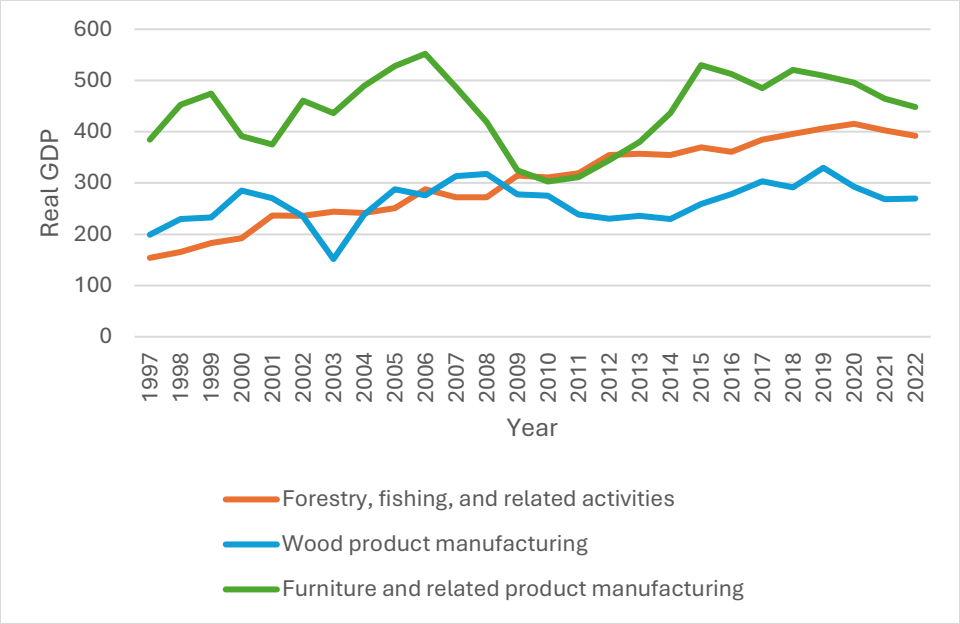


Table 1. Real GDP by industry in Colorado (millions of chained 2017 dollars) (Source: BEA)

Description	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forestry, fishing, and related activities	310.6	319.2	354.3	357.2	354.8	369.8	360.6	384.3	395.5	406.4	415.5	402.6	392
Wood product manufacturing	275	238.2	230.4	236.1	229.4	259.1	278.6	303.1	291.7	329.8	292.7	268.5	269.6
Furniture and related product manufacturing	302.9	311.7	344.7	380.2	436.3	530.2	512.4	485.4	520.5	509.7	495.5	464.5	448.5

In Figure 1, the real GDP by industry in Colorado from the BEA shows that the furniture and related product manufacturing sector is the largest among the forest product industry sectors. This sector experienced the largest decline during the Great Recession of 2008, starting to decrease its GDP from 2007, reaching a trough in 2010, and returning to the previous highest level following the Great Recession in 2015. The trend changes after 2015, where it seems to stagnate and then decline a bit in recent years from 2020 to 2022. The wood product manufacturing sector followed a similar trend to that of the furniture and related product manufacturing sector, reaching a peak before the Great Recession, experiencing a milder decline, having a longer recovery period, and reaching another peak at a similar level to the previous one. Likewise, this sector has also shown a downward trend in recent years during the COVID-19 pandemic. While less relevant to the forest product industry but providing a comparison, the forestry, fishing, and related activities sector have shown an overall upward trend from 1997 until 2022.

In Figure 2 and Table 2, compensation of employees by industry in Colorado is presented for four sectors: forestry and logging, support activities for agriculture and forestry, wood product manufacturing, and furniture and related product manufacturing. Overall, trends since 1998 in these sectors are parallel to that for real GDP. The furniture and related product manufacturing sector has the largest amount of compensation to employees, alongside its large real GDP. It dipped during the Great Recession and recovered but has not fully returned to the previous peak level. The wood product manufacturing sector shows a similar pattern. This sector reached its peak before the Great Recession, dipped, recovered slowly, but did not again reach its previous highest level. The support activities for agriculture and forestry presents an overall increase in compensation throughout the whole period except for a recent decline after the COVID-19 pandemic. The forestry and logging sector had the lowest level of compensation among the sectors.

Figure 2. Compensation of employees by industry (Source: BEA, in real terms, 2022 USD)

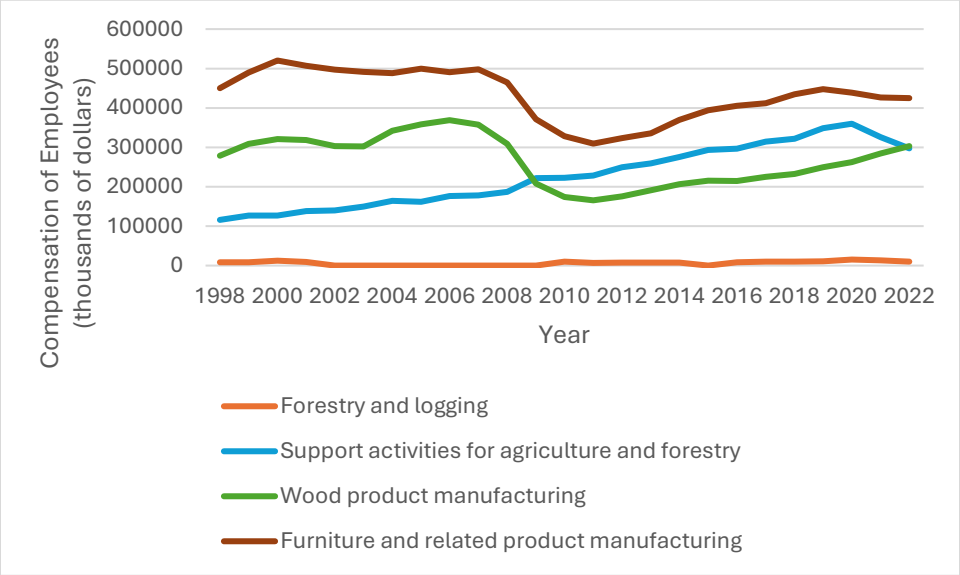


Table 2. Compensation of employees by industry (Source: BEA, in real terms, 2022 USD)

Description	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Compensation of employees by industry (thousands of dollars)											
Forestry and logging	$7,402	$7,172	$7,618	(D)	$8,092	$9,923	$10,065	$11,098	$15,289	$13,352	$9,753
Support activities for agriculture and forestry	$249,434	$259,188	$275,405	$292,964	$296,416	$314,327	$321,914	$348,273	$359,916	$326,106	$297,352
Wood product manufacturing	$176,031	$190,817	$206,856	$215,817	$214,813	$225,393	$232,503	$249,364	$262,869	$284,351	$303,504
Furniture and related product manufacturing	$323,387	$335,215	$369,302	$393,993	$405,247	$412,145	$434,627	$447,896	$439,081	$426,127	$424,959
Note. All dollar estimates are in thousands of current dollars and adjusted for inflation, using CPI from Bureau of Labor Statistics and 2022 as a base year.											
(D) Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.											

The employment aspect of the forest product industry in Colorado shows the least positive situation. Employment in the furniture and related product manufacturing and the wood product manufacturing sector declined during the Great Recession and has not recovered relative to the previous highest level. More specifically, employment in the furniture and related product manufacturing declined by 31.5% from 2007 to 2012 but recovered by 16.5% from 2012 to 2022. In the case of the wood product manufacturing sector, employment decreased by 45.6% from 2006 to 2011 but recovered by 36.9% from 2011 to 2022. This partial recovery may be partially explained by technological developments which replaced labor. Employment in the forestry and logging sector in Colorado has missing data from 2002 to 2009 and 2015. Apart from this, employment in the forestry and logging sector has remained nearly constant throughout the years until 2022. Contrary to the overall decline in employment, the support activities for agriculture and forestry indicate an increase of 43% from 1998 to 2022.

Figure 3. Total full-time and part-time employment by industry in Colorado (Source: BEA)

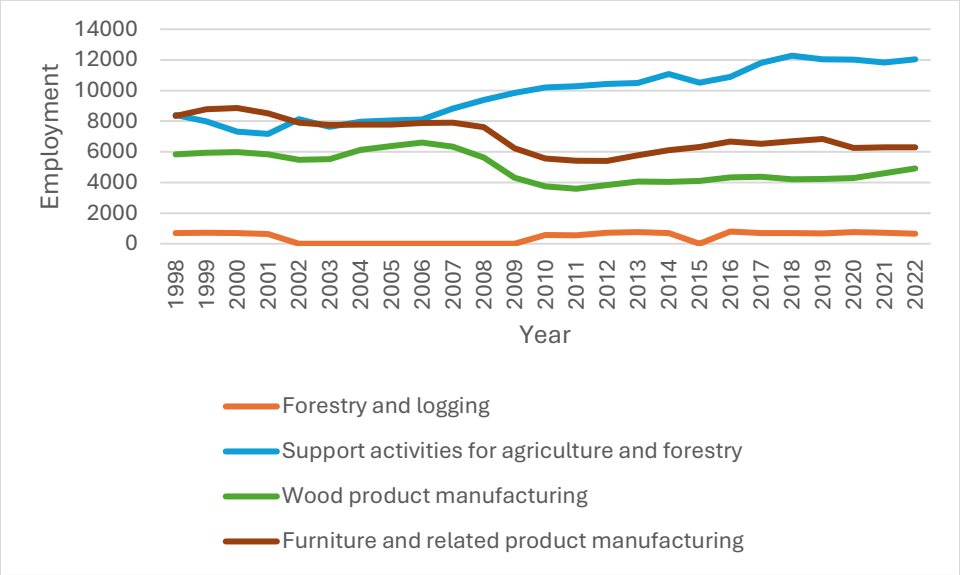


Table 3. Total full-time and part-time employment by industry in Colorado (Source: BEA)

Description	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forestry and logging	726	755	699	(D)	795	691	694	677	754	723	646
Support activities for agriculture and forestry	10,435	10,500	11,077	10,522	10,896	11,807	12,275	12,031	12,026	11,829	12,035
Wood product manufacturing	3,835	4,065	4,045	4,103	4,339	4,373	4,216	4,231	4,294	4,597	4,917
Furniture and related product manufacturing	5,407	5,776	6,111	6,306	6,667	6,522	6,690	6,836	6,245	6,303	6,300
(D) Not shown to avoid disclosure of confidential information; estimates are included in higher-level totals.											

To complement the analysis of the current state of the forest product industry in Colorado, data is also obtained from the Census Bureau which provides options to select industry sectors from 3-digit NAICS codes to 6-digit NAICS codes. The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies

in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy (*North American Industry Classification System (NAICS) U.S. Census Bureau*, n.d.). Under the 3-digit NAICS codes, the four sectors of (113) forestry and logging, (1153) support activities for forestry, (321) wood product manufacturing, and (337) furniture and related product manufacturing are relevant for forest product industry in Colorado. (322) paper manufacturing sector is excluded in our analysis after the consultation with experts in the state that Colorado has no major participation in paper manufacturing and the state's forest resources are not well-suited for supplying a paper production sector, under current market forces. (1153) support activities for forestry is used instead of (115) support activities for agriculture and forestry.

2.2 Number of Establishments and Number of Employees from Census Bureau

In Census Bureau data, there is an annual survey of County Business Patterns, which can be disaggregated into state-level by NAICS industry codes about number of establishments, annual payroll, first-quarter payroll, and number of employees. This data is available for the years 2012 to 2022. Data from 2022 is the most current data available and was used to create a snapshot of the current state of the forest product industry in Colorado.

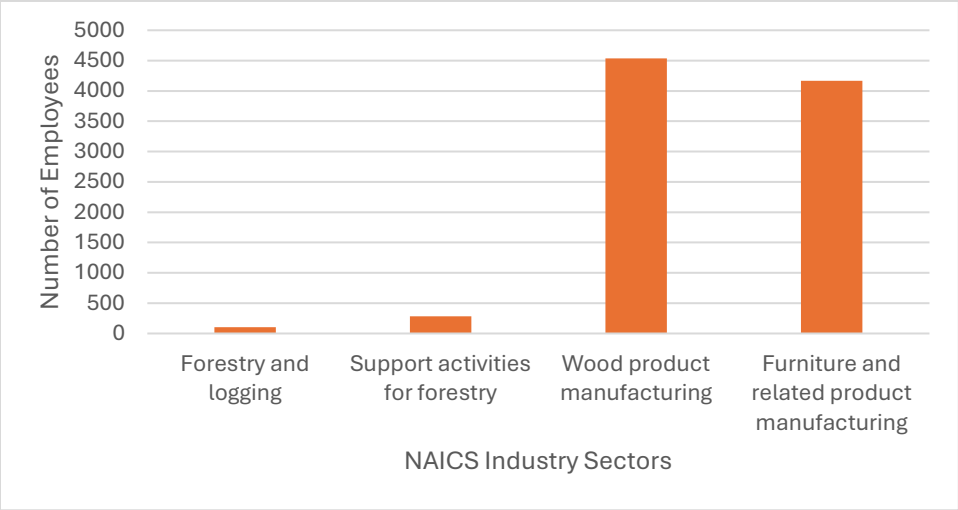
Table 4. 2022 Annual survey of county business patterns (CBP) in Colorado

(Source: Census Bureau)

2017 NAICS code	Meaning of NAICS Code	Number of establishments	Annual payroll ($1,000)	First-quarter payroll ($1,000)	Number of employees
113	Forestry and logging	34	8,318	2,265	104
1153	Support activities for forestry	34	19,662	4,156	282
321	Wood product manufacturing	206	256,357	60,588	4,536
337	Furniture and related product manufacturing	248	230,178	58,728	4,165

Figure 4. 2022 Number of employees in four sectors in the forest product industry

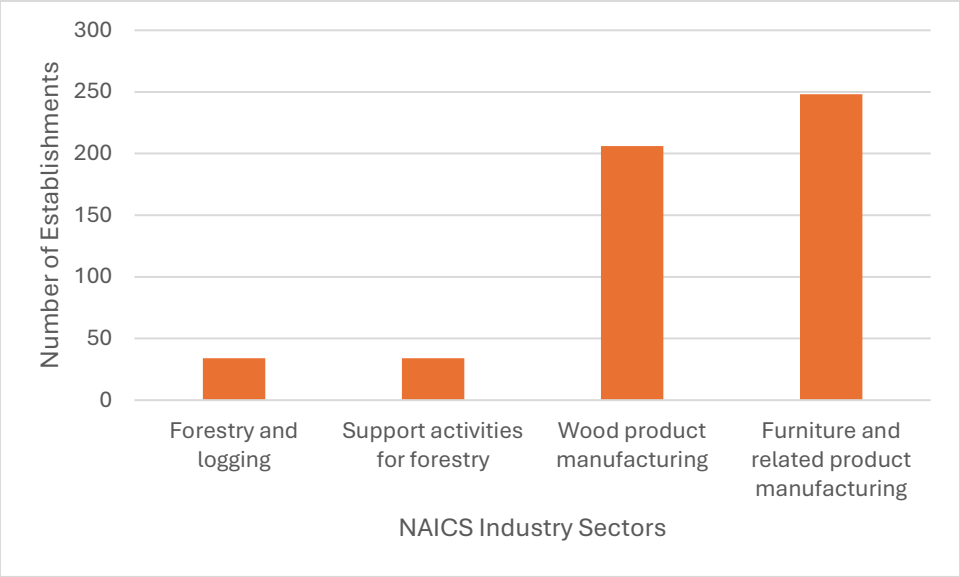
(Source: Census Bureau)



Based on Table 4, it is shown that there are 34 establishments and 104 employees in the forestry and logging sector, 34 establishments and 282 employees in the support activities for forestry sector, 206 establishments and 4,536 employees in the wood product manufacturing sector, and 248 establishments and 4,165 employees in the furniture and related product manufacturing sector in Colorado. As it is indicated in other data from BEA, the wood products and furniture and related product manufacturing are larger sectors than the forestry and logging and support activities for forestry. One thing to note is that the Census Bureau data can be disaggregated from code (115) support activities for agriculture and forestry into code (1153) support activities for forestry while BEA data does not. Figures 4 and 5 are presented to provide a better visual representation of the relative size of the four sectors in the forest product industry.

Figure 5. 2022 Number of establishments in four sectors of forest product industry

(Source: Census Bureau)



Data for the years 2012-2022 is plotted in Figures 6 and 7 to display trends in the number of establishments and the number of employees in the four forest product industry sectors analyzed for Colorado. In Figure 6, the number of establishments in all the sectors has been declining or stagnant despite slight temporary upward and downward variation. The number of establishments in the forest and logging sector decreased by 19% from 42 in 2012 to 34 in 2022, and those in the furniture and related product manufacturing sector fell by 13.9% from 288 in 2012 to 248 in 2022, which can be interpreted as an increase in consolidation in these sectors. On the other hand, while it is hardly recognized in Figure 6, the number of establishments in the support activities for the forestry sector increased by 54.5% from 22 in 2012 to 34 in 2022. The number of establishments in the wood product manufacturing sector increased by 12.5% from 208 in 2012 to 234 in 2017 but fell back to 206 by 2022.

Figure 7 is the stacked area chart of the number of employees in the four sectors in the forest product industry in Colorado. This is additional evidence for the consolidation of the forest product industry workforce into a fewer number of establishments.

Figure 6. 2012-2022 Number of establishments (Source: Census Bureau)

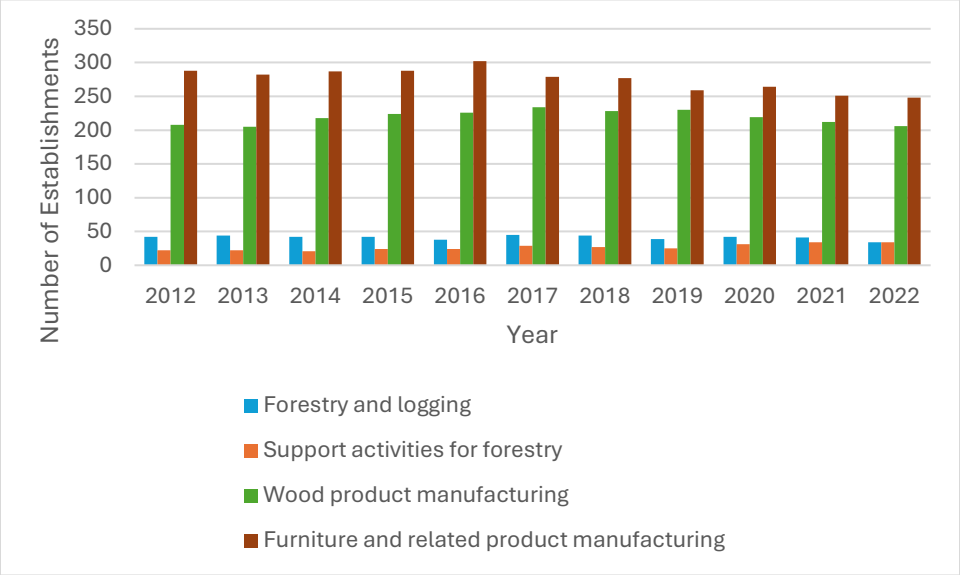
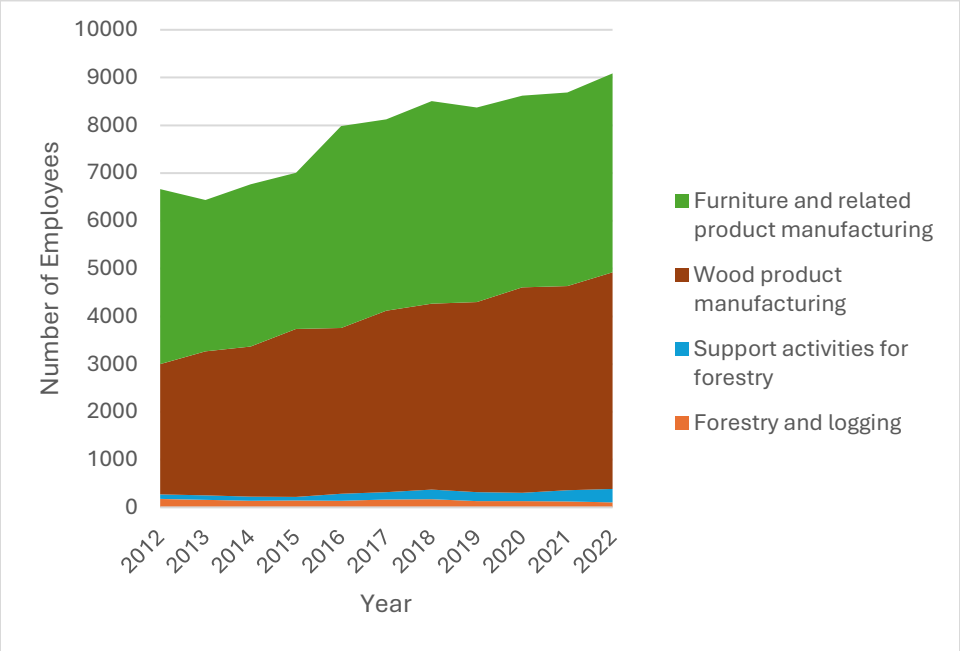


Figure 7. Stacked area chart of 2012-2022 number of employees (Source: Census Bureau)

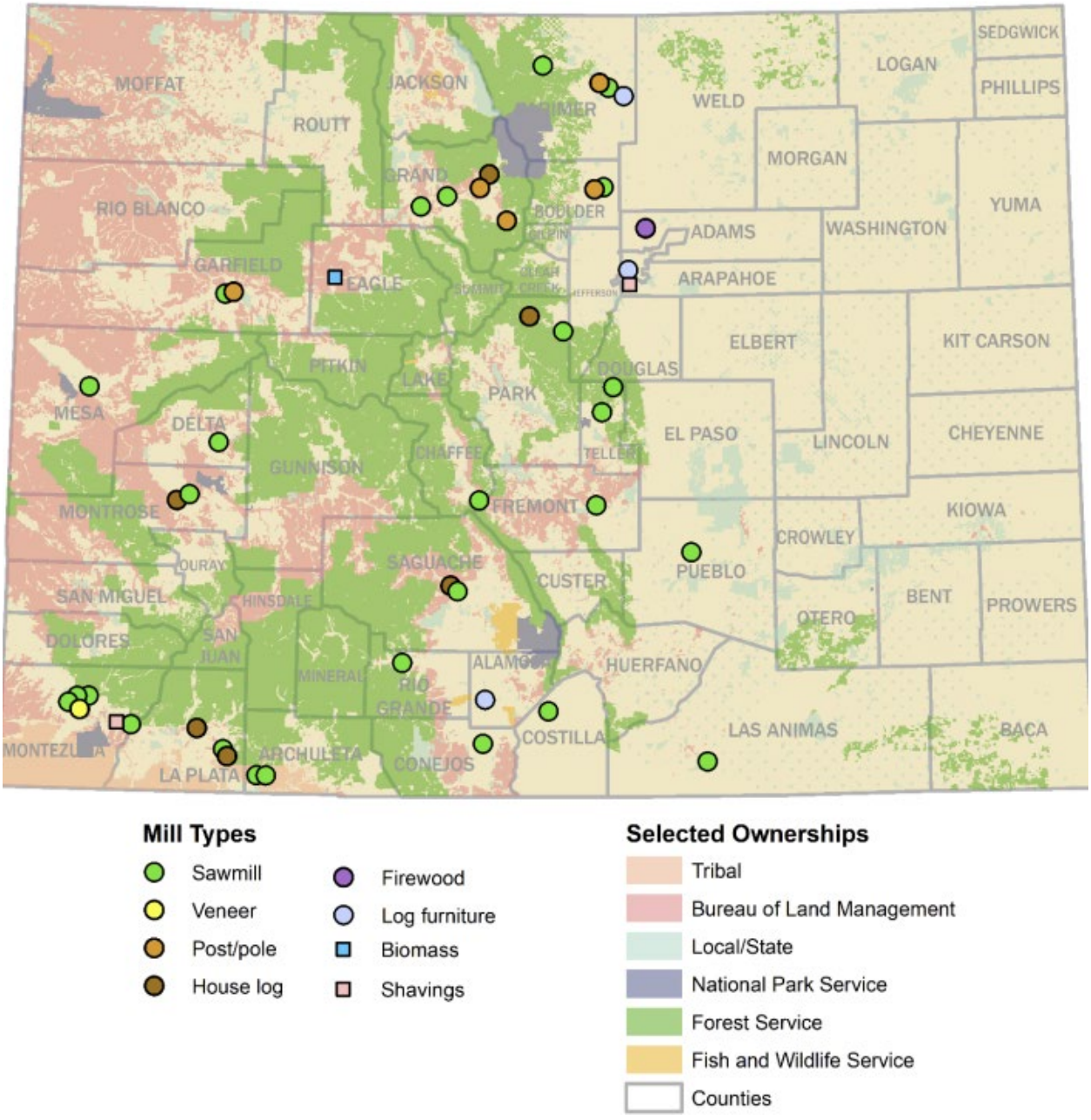


Specifically, it is worth noting the increase in the number of employees in support activities for the forestry sector and the wood product manufacturing sector. The number of employees in the support activities for the forestry sector increased over the 2012-2022 period by 200% from 94 employees in 2012 to 282 employees in 2022. The number of employees in the wood product manufacturing sector has also increased by 66.1% from 2,731 employees in 2012 to 4,536 employees in 2022. Employment in the furniture and related product manufacturing sector increased by 13.6%, from 3,665 employees in 2012 to

4,165 employees in 2022. However, the number of employees in the forestry and logging sector has declined by 40.6%, from 175 employees in 2012 to 104 employees in 2022. The increase in the number of employees in some sectors could signal growth and diversification, which can be supported by case studies of several forest product businesses in Colorado in Chapter 5 and 6 of this report. Declining employment in the forestry and logging sector can represent the decline of this sector or insufficient labor supply. Anecdotally, as a part of this research project, conversations with stakeholders in the forest product industry reveal that there is a lack of skilled labor in certain operations. There is a state workforce development grant program to encourage recruitment in this industry.

2.3 Geographic Representation of the Forest Product Mills in Colorado

Figure 8. Geographical locations of 46 forest product facilities of Colorado in 2020



(Source: Forest Industry Research Program University of Montana, 2020)

Another important aspect of understanding the forest product industry in Colorado is the geographical locations of businesses in this industry. Figure 8 displays the geographical locations of forest products facilities of Colorado in 2020 which are scattered around mountains and along the Front Range. The proximity of those sawmills to the mountains can

reduce the transportation costs of wood. However, the mountainous areas may make it difficult to connect these sawmills with each other and with other vertically integrated industries.

Table 5. Active Colorado primary wood products facilities by county and product, 2007, 2012, 2016, 2020 (original sources: Hayes and others 2012; Sorenson and others 2016; Hayes and others 2021)

County	Lumber	Veneer	House logs and log homes	Other products[a]	Total
Adams	—	—	—	1	1
Alamosa	—	—	—	1	1
Arapahoe	—	—	—	1	1
Archuleta	2	—	—	—	2
Boulder	1	—	—	1	2
Chaffee	1	—	—	—	1
Conejos	1	—	—	—	1
Costilla	1	—	—	—	1
Delta	1	—	—	—	1
Denver	—	—	—	1	1
Eagle	—	—	—	1	1
Fremont	1	—	—	—	1
Garfield	1	—	—	1	2
Grand	2	—	1	2	5
La Plata	1	—	2	—	3
Larimer	2	—	—	2	4
Las Animas	1	—	—	—	1
Mesa	1	—	—	—	1
Montezuma	4	1	—	1	6
Montrose	1	—	1	—	2
Park	1	—	1	—	2
Pueblo	1	—	—	—	1
Rio Grande	1	—	—	—	1
Saguache	1	—	1	—	2
Teller	2	—	—	—	2
2020 Total	**27**	**1**	**6**	**12**	**46**
2016 Total	30	—	10	15	55
2012 Total	31	—	12	15	58
2007 Total	30	—	19	15	64

[a]Other products include excelsior, fuel pellets, posts, poles, log furniture, and biomass/energy.

(Exported from: Forest Industry Research Program University of Montana, 2020)

3. Economic Impacts of Public Funding

In the field of regional economic analysis, there has been confusion and inconsistency between the usage of *economic contribution* and *economic impact* analysis. Thus, it is important to define each type of economic analysis. Watson et al. (2007) define economic activity as "dollars spent within region that are attributable to a given industry, event, or policy" (p.142). While economic activity analysis tracks the flow of dollars spent within a region, economic contribution and economic impact analysis are types of economic activity analysis (Watson et al., 2007).

Economic contribution analysis gives a broader picture of how the economic activity cycles through the region's existing economy, which is defined as "the gross changes in economic activity that can be attributed to a given industry, event, or policy" (Watson et al., 2007, p.141). This analysis is based on the input-output model that measures economic activity by tracking the financial linkages in a regional economy between industries, households, and institutions (Watson et al., 2007). Economic contribution analysis first calculates output multipliers of each industry sector, defined as how much an industry's economic activity multiplies gross sales in the other sectors of the regional economy. The next step is to multiply each industry sector's current final demand with its output multiplier to produce the total economic contribution of the industry to the regional economy.

On the other hand, economic impact analysis measures the net changes in new economic activity associated with an industry, event, or policy in an existing regional economy (Watson et al., 2007). The net changes in economic activity could be negative after previously existing economic activities are replaced by new economic activity.

An important theoretical foundation of economic activity analysis is economic base theory. This theory posits that economic activity or output is created through final demand, especially exogenous sales of a given sector such as exports. Factors such as import substitution, capital investment, and innovation are all drivers of a regional economy. However, for small regions, exports and the associated new dollars brought into the region are the main contributors to the region's economic growth (Watson et al., 2015). Thus, each economic contribution and impact analysis is the ex-post and ex-ante effects on economic activity in a region from the exogenous sales of a given sector.

3.1 Exogenous Demand for the Forest Product Industry through USDA Wood Innovations Program Grants

One of the key aspects of the current research project, the economic and community contribution analysis of forest product industry in Colorado, is to assess the impact of public

investment from federal and state institutions on the forest product industry in Colorado. The Wood Innovation Program, administered by the United States Department of Agriculture (USDA), is a primary funding source from the federal government.

The purpose of this program is to seek sustainable supply of wood to make forest products by investing in local wood economies through its grant programs, which makes forests healthier and communities more prosperous. These grants encourage innovation, develop wood energy markets, and promote wood as a sustainable building material. There are three grant categories offered under this program: Wood Innovation, Community Wood, and Wood Products Infrastructure Assistance. Colorado was awarded in the Wood Innovation and Wood Products Infrastructure Assistance grant categories in 2024 (*Wood Innovations Program Grants*, n.d.).

Among the three categories, Wood Innovation Grants are awarded to proposals that expand traditional wood utilization projects, facilitate using wood as a construction material in commercial, institutional, and multifamily buildings, and develop wood energy markets. These grants are expected to support healthier forest product economies, which is critical to healthy forests by removing excessive fuels of wildfire and lowering wildfire risks to communities (*Wood Innovations Program Grants*, n.d.). Table 6 lists the 2024 awardees in Colorado and funding amounts.

Table 6. 2024 awardees of Wood Innovation Grants in Colorado (Source: USDA Forest Service)

Applicant / Title	Funding
Colorado School of Mines: Expanding the Ponderosa Pine Mass Timber Market for Residential and Commercial Construction with Field Benefits Demonstration	$299,193
Eagle Wood Cutting and Processing: EagleWood Biomass Production Program	$81,290
EcoTech Biofuels, LLC: Project Planning for Rio Grande Biofuels	$300,000
KFB Forestry, LLC: Wood Utilization from Forest Mitigation Projects	$58,470
Lignum Support, LLC: Front Range Forest Products Sawmill Startup	$300,000
Redstones Timber Frames, Inc: ModVern Cabins: Standing Dead, Engelmann Spruce, Stackable Log Packages for Affordable Housing	$280,500

Routt Millworks, LLC: Sawmill Improvement Phase 2 - New Hurdle Machine Works Heavy Duty System	$175,000
Timber Age Systems, Inc: Ponderosa Pine Mass Timber Blueprints Enabling Local, High-Performance, Affordable, Attainable and Sustainable Off-Site Housing	$190,494
Yosemite Clean Energy, LLC: Feedstock Analysis and Pre-Engineering to support development of a wood waste to biofuel gasification plant in the San Luis Valley, Colorado	$300,000

Wood Products Infrastructure Assistance Grants provide funding to wood processing facilities to improve, establish, retrofit, or expand facilities that purchase and process byproducts from ecosystem restoration projects from federal or tribal lands. These facilities are in areas at risk of unnaturally severe wildfire or insects and disease (*Wood Innovations Program Grants*, n.d.). Table 7 lists the 2024 awardees of Wood Products Infrastructure Assistance Grants in Colorado and how much funding they were awarded.

Table 7. 2024 awardees of Wood Products Infrastructure Assistance Grants in Colorado

(Source: USDA Forest Service)

Applicant / Title	Funding
Biochar Now, LLC: Biochar Now's Northern Colorado Biochar Production Site Expansions	$750,000
Golden West Pine Mills, LLC: Increasing Mill Capacity for Existing EGAR/Mass Timber Manufacturing Facility	$933,325

These USDA Wood Innovation Program Grants come from a federal governmental organization and are considered exogenous to the Colorado economy, bringing new dollars to the forest product industry in Colorado, not replacing any existing economic activity and being considered as net changes in economic activity. Thus, these grants are suitable for conducting an economic impact analysis.

3.2 Economic Impact Analysis of USDA Wood Innovation Program Grants

To conduct an economic impact analysis, 2022 Colorado Industry by Industry Social Accounting Matrix (SAM) in 3-digit NAICS codes was exported from IMPLAN Cloud software. On the spreadsheet of this SAM, total demand, and total supply by industry sectors in 3-digit NAICS codes are connected.

IMPLAN Cloud is a software that combines data and analytics to contribute to greater understanding of economic impact based on economic input output modeling. It was developed in the 1980s by a team led by Greg Alward in Fort Collins as a Forest Service tool to help with forest planning. IMPLAN Cloud data contains over 500 industries. Industry data include employment, labor income, revenue, and intermediate input expenditures. Commodity-level data elements include foreign and domestic trade of goods and services and household and government commodity demand. Geographic and demographic data elements include household counts by nine household income categories, savings rates, commuting rates, regional GDP, and an economic diversity index. These data are updated annually. The U.S. Bureau of Economic Analysis (BEA), the U.S. Department of Agriculture (USDA), the U.S. Bureau of Labor Statistics (BLS), and the U.S. Census Bureau are the main raw data sources. IMPLAN Cloud is used by companies large and small – from the largest technology companies, federal government, financial service companies, healthcare organizations, consulting firms, and universities – to the smallest local governments, economic development organizations, and boutique consultants.

The social account of total aggregate demand for a region consists of intermediate demand among sectors and final demand for goods and services by institutions such as households, private and public investments, and exports. Details of the SAM are provided in Appendix A.

Table 8. The result of economic impact analysis of USDA Wood Innovation Program Grants

Industry Sector in 3-digit NAICS	Change in Final Demand		IMPACT	New Output
111 - Crop Production	$0		$36,107	$2,494,978,393
112 - Animal Production and Aquaculture	$0		$63,601	$6,440,116,642
113 - Forestry and Logging	$314,000	Eagle Wood Cutting and Processing, KFB forestry, Route Millworks	$359,737	$123,714,049
114 - Fishing, Hunting and Trapping	$0		$488	$74,548,198
115 - Support Activities for Agriculture and Forestry	$1,050,000	Biochar Now, Lignum Support	$1,076,146	$366,716,413
211 - Oil and Gas Extraction	$0		$215,118	$24,526,663,495
212 - Mining (except Oil and Gas)	$0		$23,860	$2,864,389,930
213 - Support Activities for Mining	$0		$75,669	$12,748,199,943
221 - Utilities	$600,000	EcoTech Biofuels, Yosemite Clean Energy	$921,806	$14,189,571,139
23 - Construction	$0		$123,378	$54,012,825,437
311 - Food Manufacturing	$0		$150,071	$18,478,866,043
312 - Beverage and Tobacco Product Manufacturing	$0		$35,452	$4,872,739,896
313 - Textile Mills	$0		$341	$34,398,290
314 - Textile Product Mills	$0		$2,680	$294,919,909
315 - Apparel Manufacturing	$0		$2,082	$233,388,747
316 - Leather and Allied Product Manufacturing	$0		$413	$46,485,250
321 - Wood Product Manufacturing	$1,703,000	Golden West Pine Mill, Colorado School of Mines, Redstone Timber Frames, Timber Age Builders	$1,901,492	$1,774,719,460

In Table 8, it is shown where each forest product business' grant is assigned and aggregated in the column of "Change in Final Demand", which is an exogenous change in the final demand of the forest product industry by federal grants by USDA. Multipliers capture the interconnection by financial purchases between industry sectors and endogenous institutions such as households, employee compensation, other property type income, proprietor income, and tax on production and imports. Multipliers in each industry sector are used to translate these changes in Final Demand to the "IMPACT" column which illustrates the economic activities created in each industry sector by changes in exogenous demand on the forest product industry by USDA federal grants.

The forest product industry sectors of (113) forestry and logging, (115) support activity for agriculture and forestry, and (321) wood product manufacturing, and other industry sectors have the impact of created economic activities stemming from additional final demand on the forest product industry. Since this whole result is based on 2022 Colorado industry by industry Social Accounting Matrix (SAM), the result of these economic impacts

are ex-ante estimates of newly created economic activities by 2024 Wood Innovation Program Grants, and the column of "New Output" is the addition between 2022 output of a respective industry sector and estimated economic activities in the column of "IMPACT."

Table 9. Top 15 impacts of created economic activities by USDA Wood Innovation Program Grants

Rank	Industry Sector in 3-digit NAICS	Change in Final Demand	IMPACT
1	Households 100-150k	$0.00	$2,975,166.39
2	321 - Wood Product Manufacturing	$1,703,000.00	$1,901,491.73
3	Enterprises (Corporations)	$0.00	$1,568,028.12
4	115 - Support Activities for Agriculture and Forestry	$1,050,000.00	$1,076,146.00
5	221 - Utilities	$600,000.00	$921,806.46
6	Households 70-100k	$0.00	$671,737.12
7	42 - Wholesale Trade	$0.00	$612,087.52
8	541 - Professional, Scientific, and Technical Services	$0.00	$609,590.59
9	Households 50-70k	$0.00	$537,285.49
10	Households 40-50k	$0.00	$509,684.14
11	531 - Real Estate	$0.00	$495,175.10
12	Households GT200k	$0.00	$493,106.41
13	113 - Forestry and Logging	$314,000.00	$359,737.34
14	Employee Compensation	$0.00	$302,605.88
15	Tax on Production and Imports	$0.00	$252,069.12

Table 9 lists "IMPACT" from largest to smallest and shows from the first rank to the 15th. For example, the wood product manufacturing sector received a total of $1,703,000 grant in 2024 which is estimated to create $1,901,491 value of economic activities in that sector. While those sectors that received large amounts of grant funding show economic activity impacts, even sectors that did not directly receive funding show increased economic activity. For example, Households 100-150k, that is households whose income level is between $100,000 and $150,000, show the largest predicted impact, but without any change in final demand. This group shows a predicted increase in economic activity of $2,975,166, despite no exogenous change.

The sum of the "IMPACT" throughout all industry sectors and endogenous institutions in Colorado is the total economic impact of creating economic activities by 2024 USDA Wood Innovation Program Grants in Colorado, $17,259,396. The total amount of 2024 federal grants in Colorado are $3,667,000. The total value of economic activities is 4.71 times the total value of grants awarded, $3,667,000. This result should form an important part of the assessment of public funding on the forest product industry and guidance of future legislature process of public funding.

4. Economic Contribution Analysis of Colorado's Forest Product Industry

An evaluation of the economic contribution of Colorado's forest product industry estimates the cumulative effects of spending within the sector and accounts for how it cycles through the state's economy ("THE 2019 FOREST REPORT," 2019).

An input-output (I-O) model using a Social Accounting Matrix (SAM) is the most common method for economic contribution analysis. A SAM of 2022 Colorado exported from IMPLAN software is used for the current analysis, which is the most recent data available. A SAM is "a statistical framework that utilizes double-entry bookkeeping to trace all monetary flows within a regional economy over a given period" ("THE 2019 FOREST REPORT," 2019, p.45).

From IMPLAN software, we can export the industry details of Colorado in 2022 in terms of total output, wage and salary employment, employee compensation, proprietor employment and income, other property income, and taxes on production and imports net of subsidies, which can give general statistics of the forest product industry shown in Table 10.

Table 10. Forest product industry details of Colorado in 2022

Industry Code	Description	Total Output	Wage and Salary Employment	Employee Compensation	Proprietor Employment	Proprietor Income	Other Property Income	Taxes on Production and Imports Net of Subsidies
3	113 - Forestry and Logging	$123,354,312.11	582.9	$49,487,580.80	549.74	$7,342,865.36	$21,860,327.47	$2,506,127.37
5	115 - Support Activities for Agriculture and Forestry	$365,640,266.87	5,390.12	$291,665,854.22	5,475.24	$4,810,036.69	$410,569.94	$12,611,663.71
17	321 - Wood Product Manufacturing	$1,772,817,967.79	3,991.69	$307,804,260.78	737.66	$1,610,245.84	$180,413,988.73	$8,511,633.94
30	337 - Furniture and Related Product Manufacturing	$1,497,803,180.12	5,382.73	$419,931,815.37	767.66	$17,826,343.46	$73,165,973.20	$6,094,370.60

The methodology used here follows the analysis done in the 2019 Forest Report from Oregon Forest Resources Institute by Olli-Pekka Kuusela, David Rossi, Greg Latta, Philip Watson, Tim Nadreu.

The base economic contribution of the forest product industry in Colorado consists of direct and indirect/induced effects. The direct effects are "the new dollars or jobs brought into the state of" Colorado and the indirect/induced effects are "the jobs created in other sectors from the linkages of the forest product industry to the broader state economy" ("THE 2019 FOREST REPORT," 2019, p.45). The indirect effects consider created economic activity

by the forest product industry through input purchases (i.e., supply chain) from other sectors of the Colorado economy. The induced effects count economic activities that the forest product industry induces by paying wages, salaries, and profits to Colorado households who then use that income to purchase goods and services from other sectors. Table 11 shows a breakdown of the economic base contributions in terms of both direct and indirect/induced effects.

In Table 11, "gross" contribution can be compared to "base" contribution of the forest product industry. "Gross" contribution in terms of output, employment, and value added are descriptive statistics of these forest product sectors reported in the industry details of IMPLAN software, which are based on government statistics in secondary data sources (e.g., BEA, BLS, Census).

> "Gross values are defined as the directly observable employment and wages paid in a given sector. These are the values that are reported in government statistics. Base values are economic contributions that include the regional economic effect of that sector's production and how it spawns activity within other sectors. The total base contribution is calculated as the sector's sales outside the state times the sector's multiplier" ("THE 2019 FOREST REPORT," 2019, p.74).

Here is an example explaining the difference between "base" contribution and "gross" contribution: if a sawmill in Colorado has twenty people on its payroll, then the "gross" employment of that sawmill is twenty. However, "base" contribution can be bigger than twenty since it measures a sector's ability through its exports to draw in new dollars to the region and how those dollars create economic activity (i.e. jobs and income) not only in that sector but also in other sectors of the economy ("THE 2019 FOREST REPORT," 2019). Another example could be a store selling a saw blade to a sawmill. The gross analysis considers the saw blade sale as the contribution of the retail store while the base analysis credits the forest product industry instead of the retail sector because the saw blade sale is enabled by the base industry, the sawmill, bringing new dollars to Colorado through exports and creating the demand of the saw blade in the retail sector.

This economic "base" analysis can also be understood as "contribution of exports" in that it posits that "the source of economic growth is exports", exogenous sales to outside of a region, and it is suitable for "developing policies that increase sales, jobs, and income through exports" ("THE 2019 FOREST REPORT," 2019, p.75). To avoid the double-counting problem which has been a primary criticism on economic contribution analysis, the total output, employment, and value added in the "gross" analysis should be the same with those total numbers in the "base" analysis while they are distributed differently among industry sectors.

Table 11. Direct effect and indirect/induced effect of economic base contribution in 2022

Industry Sector	Base Contribution	Direct Effect	Indirect/Induced Effect	Total	Gross Contribution
113 Forestry and Logging	Output	$75,740,145	$93,406,539	$169,146,684	$215,824,064
	Employment	734	515	1,248	1,982
	Value Added	$52,588,952	$49,613,773	$102,202,725	$142,064,309
115 Support Activity for Agriculture and Forestry	Output	$59,960,491	$76,562,081	$136,522,573	$523,682,812
	Employment	1,783	338	2,121	15,562
	Value Added	$50,793,154	$42,370,132	$93,163,286	$443,274,067
321 Wood Product Manufacturing	Output	$634,188,507	$1,263,084,167	$1,897,272,674	$2,498,102,426
	Employment	1,885	4,730	6,616	6,664
	Value Added	$198,650,965	$635,203,848	$833,854,813	$702,217,999
337 Furniture and Related Product Manufacturing	Output	$1,328,647,469	$2,556,489,452	$3,885,136,921	$2,564,770,174
	Employment	5,487	10,027	15,514	10,532
	Value Added	$461,233,118	$1,353,039,545	$1,814,272,663	$885,319,014
Forest Product Industry (aggregation)	Output	$2,098,536,612	$3,989,542,239	$6,088,078,851	$5,802,379,476
	Employment	9,889	15,610	25,499	34,739
	Value Added	$763,266,188	$2,080,227,298	$2,843,493,487	$2,172,875,389

The economic base model results indicate that the forest product industry, the aggregation of (113) forestry and logging, (115) support activity for agriculture and forestry, (321) wood product manufacturing, and (337) furniture and related product manufacturing, contributes over $6,088 million output, 25,499 jobs, and over $2,843 million value added (state gross domestic product) to Colorado's economy. These contributions are 0.59% of total state output, 0.57% of state employment, and 0.49% of state GDP. It should be noted that base contributions of the forest product industry in terms of output and value added are even larger than gross contributions. While gross contributions in each output and value added are $5,802 million and $2,172 million, base contributions in them are $6,088 million and $2,843 million, respectively. Larger base contribution than gross contribution means that exogenous demands on the forest product industry create not only economic activities within itself but also in other sectors in Colorado through supply chains, making more contribution than what we can see from government statistics on the surface. On the other hand, the base contribution in employment, 25,499, is lower than the gross contribution, 34,739, implying that the forest product industry does not create and multiply jobs.

To have a deeper understanding of the base contribution of the forest product industry in 2022, it is advantageous to compare it with values from an earlier year. The same procedure for economic contribution analysis was implemented using the SAM of Colorado in 2016 exported from IMPLAN. Table 12 displays the result of base contribution analysis in 2016. By comparison, while it is shown that every contribution in both base and gross has increased, base contributions in output and value added have increased by a bigger degree, 121% and 129% respectively, than gross contributions in output and value added which have

increased by 114% and 106%. A higher increase in base contribution than gross contribution means that the forest product industry in Colorado has improved in bringing new dollars to the local economy and keeping that money circulating within it for its economic development.

Table 12. Direct effect and indirect/induced effect of economic base contribution in 2016

Industry Sector	Base Contribution	Direct Effect	Indirect/Induced Effect	Total	Gross Contribution
113 Forestry and Logging	Output	$8,806,932	$9,444,953	$18,251,886	$39,855,898
	Employment	167	74	242	702
	Value Added	$2,833,775	$5,080,715	$7,914,490	$11,870,700
115 Support Activity for Agriculture and Forestry	Output	$74,296,283	$69,961,719	$144,258,003	$498,972,783
	Employment	1,744	482	2,226	11,698
	Value Added	$53,300,758	$39,610,724	$92,911,483	$357,449,029
321 Wood Product Manufacturing	Output	$301,205,830	$306,743,785	$607,949,615	$910,544,565
	Employment	1,429	1,878	3,307	4,045
	Value Added	$83,653,356	$162,098,823	$245,752,178	$236,871,421
337 Furniture and Related Product Manufacturing	Output	$1,060,092,223	$929,376,220	$1,989,468,443	$1,255,913,652
	Employment	5,464	5,866	11,329	6,436
	Value Added	$381,148,195	$514,596,447	$895,744,642	$449,006,796
Forest Product Industry (aggregation)	Output	$1,444,401,269	$1,315,526,677	$2,759,927,946	$2,705,286,898
	Employment	8,804	8,300	17,104	22,881
	Value Added	$520,936,084	$721,386,709	$1,242,322,793	$1,055,197,946

To understand the relative importance of the forest product industry in Colorado compared to other industry sectors in 2022, Table 13 sorted 2022 base output of each industry sector from the largest to the smallest up to the 15th. While there is no forest-product-related sector within the ranking fifteen industry sectors, the furniture and related product manufacturing sector is placed at 34th, the wood product manufacturing sector at 45th, the forestry and logging sector at 69th, the support activities for agriculture and forestry sector 72nd out of entire 87 industry sectors in 3-digit NAICS categorization. Table 14 and 15 list the top 15 industry sectors in terms of 2022 base employment and base value-added. According to base employment, the furniture and related product manufacturing sector is placed at 34th, the wood product manufacturing sector at 52nd, the support activities for agriculture and forestry sector 65th, and forestry and logging sector at 70th. According to base value-added, the furniture and related product manufacturing sector is placed at 34th, the wood product manufacturing sector at 50th, the forestry and logging sector at 69th, and the support activities for agriculture and forestry sector 70th.

Table 13. Comparison of base output of other sectors to the forest product industry

Rank	Industry Sector	Base Output
1	23 - Construction	$114,864,775,115.86
2	541 - Professional, Scientific, and Technical Services	$106,272,232,273.36
3	9B - Administrative Government	$89,788,891,295.35
4	211 - Oil and Gas Extraction	$45,901,177,252.78
5	311 - Food Manufacturing	$42,906,805,333.47
6	42 - Wholesale Trade	$37,508,071,905.24
7	334 - Computer and Electronic Product Manufacturing	$35,769,812,873.78
8	531 - Real Estate	$29,667,765,880.64
9	213 - Support Activities for Mining	$26,904,636,007.08
10	518 - Data Processing, Hosting, and Related Services	$18,104,780,662.00
11	517 - Telecommunications	$17,727,507,125.28
12	333 - Machinery Manufacturing	$17,439,712,768.52
13	325 - Chemical Manufacturing	$17,401,915,724.62
14	481 - Air Transportation	$15,692,464,621.94
15	336 - Transportation Equipment Manufacturing	$15,430,006,300.79

Table 14. Comparison of base employment of other sectors to the forest product industry

Rank	Industry Sector	Base Employment
1	9B - Administrative Government	664,673
2	23 - Construction	534,661
3	541 - Professional, Scientific, and Technical Services	495,983
4	311 - Food Manufacturing	143,173
5	42 - Wholesale Trade	139,155
6	334 - Computer and Electronic Product Manufacturing	113,284
7	211 - Oil and Gas Extraction	111,490
8	531 - Real Estate	92,604
9	213 - Support Activities for Mining	76,119
10	721 - Accommodation	62,858
11	518 - Data Processing, Hosting, and Related Services	58,916
12	333 - Machinery Manufacturing	56,993
13	517 - Telecommunications	55,075
14	325 - Chemical Manufacturing	50,983
15	481 - Air Transportation	49,836

Table 15. Comparison of base value-added of other sectors to the forest product industry

Rank	Industry Sector	Base Value-added
1	9B - Administrative Government	$71,197,498,723.49
2	541 - Professional, Scientific, and Technical Services	$63,402,988,069.57
3	23 - Construction	$63,117,862,637.62
4	211 - Oil and Gas Extraction	$23,906,691,146.76
5	42 - Wholesale Trade	$20,558,567,836.42
6	531 - Real Estate	$18,510,142,115.51
7	334 - Computer and Electronic Product Manufacturing	$17,570,012,071.61
8	311 - Food Manufacturing	$16,771,050,846.57
9	213 - Support Activities for Mining	$15,179,082,810.88
10	517 - Telecommunications	$9,431,794,844.05
11	518 - Data Processing, Hosting, and Related Services	$9,202,557,501.65
12	481 - Air Transportation	$8,505,996,983.34
13	336 - Transportation Equipment Manufacturing	$8,027,235,955.59
14	325 - Chemical Manufacturing	$7,639,416,452.21
15	333 - Machinery Manufacturing	$7,600,538,914.01

5. Agricultural and Ecological Contribution of Forest Product Industry

Previous chapters of economic impact and contribution analysis give quantitative aspects of economic contribution of the forest product industry to Colorado economy. Chapter 5 provides a closer look at the qualitative aspects of the forest product industry's contributions to agriculture and ecological functions.

5.1 Agricultural Contribution

Soilless growing media and compost manufacturers in Colorado rely on the forest product industry for materials such as sawdust, woodchips, and boiler ash. For example, Summit County Resource Allocation Park (SCRAP) produces Class III composts that meet EPA 40 CFR 503 standards. The composts can be used with all plant types in any type of soil (sandy or clay) and enhance overall soil structure and improve movement of air and water within the soil – essential to healthy plant growth. The composts are produced from a combination of several feedstocks, including beetle kill wood waste, biosolids, and at times, treatment plant residuals (*Summit County, CO - Official Website*, n.d.). This factor of beetle kill wood waste represents reliance on the forest product industry which in turn contributes to agriculture production and land reclamation. While beetle kill wood in forests can fuel disastrous wildfires, utilizing this type of woods for products can reduce the cost of active management of forests, lowering the possibility of large-scale wildfires. Paonia Soil Co. in Paonia, and Rocky Mountain Soils in Alamosa are examples of companies producing soilless growing media from wood waste streams.

This dependency of soilless growing media and compost manufacturers on the forest product industry is captured in the input-output model in Chapter 3 and 4 as financial flows between agricultural industry and the forest product industry and reflected quantitatively in the output multipliers and economic base contribution. This qualitative illustration of economic contribution of the forest product industry complements the quantitative analysis in Chapter 3 and 4.

5.2 Ecological Contribution

Historically, forest management focused on fire suppression; the landscape in parts of Colorado was changed because of these past policies. In some forests, trees are overcrowded and increasingly susceptible to insects and disease. These forests often have high numbers of standing dead trees and dead trees lying on the ground, which increases the likelihood of large fires with intense fire behaviors. However, in recent years, to reduce fire fuel and the spread of wildfires, crown spacing is implemented in strategic areas by

thinning to space out the tree crowns (tops of trees) and pruning to reduce ladder fuels. Ladder fire fuels allow fire to climb from the ground up into tree crowns, where it can then jump from tree to tree. Fire in a thinned stand, where the crowns of trees are spaced out, can be kept on the ground, making it much easier to control. This crown spacing creates openings, wider spacing between trees while the remaining trees have more room to grow and less competition for water and sunlight. Timber harvest operations can also create firebreaks and reduce ground fuel (Colorado Parks and Wildlife, n.d.).

In addition, there is an association between insects and fire. In lower elevation forests, where fire has been suppressed and forest management activities have been excluded, trees have become very dense, creating competition for resources. Insects, such as mountain pine and spruce beetles, are native and natural in Colorado forests. However, they thrive on trees stressed under current conditions of high density and cycles of drought. The beetle larvae eat the inner tree bark, reducing the flow of nutrients and water, stressing, or killing the tree. Some beetles also introduce blue-stain fungi which may contribute to tree mortality. Trees that have recently been attacked by insects are fuel hazards and may increase the probability of severe wildfire. Professional foresters can help increase resistance to insects and disease by reducing the density of trees using both natural and prescribed fire. Foresters also cut and thin trees to improve forest vigor, increase diversity of wildlife habitat, provide recreation opportunities, provide wood to the public, reduce fuel hazards, and grow new trees (Colorado Parks and Wildlife, n.d.).

Forest product businesses, which utilize dead and dying trees and reduce wildfire risks through timber harvests in dense forests, significantly contribute to watershed management. This contribution is difficult to quantify because its value primarily comes from loss prevention and loss reduction. However, recent large-scale wildfire incidences provide estimates of loss to water systems. For example, the Marshall Fire happened on December 30th, 2021, and was fueled by drought and hurricane-force wind. Fire jumped from one home to the next, moving in unpredictable and unprecedented ways and burning down more than 1,000 homes. The Marshall Fire was not just the most destructive wildfire the state had ever seen. As thousands fled the windswept fire and embers, it quickly became Colorado's most documented natural disaster as well (9NEWS & Fruition, n.d.). The Marshall Fire also caused millions of dollars in damage to six public water systems including infrastructure damage, contamination, power loss, and sedimentation. Another recent example is the Alexander Mountain Fire which has burned over 9,600 acres according to the U.S. Forest Service Roosevelt National Forest. A Burned Area Emergency Response (BAER) survey evaluates the burned area, identifying watersheds that have increased potential for flooding, erosion, debris flows and rockslides. Changes in soil properties are the primary cause of increased post-fire erosion, flooding, and debris flow potential. The fire destroyed

27 homes and damaged four others in addition to destroying 21 outbuildings according to the Larimer County Assessor (Willard, 2024).

This ecological contribution of the forest product industry in terms of preventing large-scale wildfires can have a significant impact on the multipliers and base contribution in the economic models in Chapter 3 and 4. The supply of raw materials from active forest management to the forest product industry results in affordable products, which then can attract more demand on the forest products, increasing the base contribution of the forest product industry.

6. Present and Emerging Trends in Forest Products and Services

Throughout this summer internship, several trips were made to visit forest product businesses. Based on interviews with personnel in the businesses, the following present and emerging trends in the forest product industry are illustrated.

Emerging trends with new technologies can extend and diversify the connections between the forest product industry and other industries. For example, mass timber products are increasingly purchased by construction industry businesses as mass timber markets grow, woody biomass is utilized in carbon sequestration businesses, and biochar from dead or stressed trees can be used for new applications. This can also be reflected in the multiplier of the forest product industry and increase the base contribution of it. Public grants from state and federal institutions enable innovations in the forest product industry and enhance potential economic contribution.

6.1 Mass Timber Products

With access to plentiful, renewable forest resources, forest product businesses represent opportunities to reinvigorate rural areas, particularly in the design and construction sector where mass timber is used. Barth and Mesia (2024) explained various advantages and prospects of mass timber products: 1) Large-scale, continuous use of mass timber construction materials can stabilize and expand the wood products supply chain while also boosting rural economies. 2) Time and money can be saved by framing mass timber projects 20–30% faster than corresponding steel or concrete structures. 3) Because mass timber requires just 25% of the work force for installation and creates higher paid jobs in factories, it offers a financially viable solution to the problems of declining labor availability in the building trades and increasing labor prices. The 2021 International Building Code's historical revisions allow mass timber structures to be significantly larger in both area and height (Barth & Mesia, 2024).

Colorado is within the top 5 nationally in the use of mass timber despite not having a manufacturing presence. This is one of the reasons behind the establishment of the Colorado Mass Timber Coalition. The Coalition represents affordable housing, architects, foresters, and forest product manufacturers in seeking to establish a mass timber manufacturing infrastructure in Colorado. The following is the introduction of the two innovative businesses producing mass timber products in Colorado.

- Timber Age Systems in Durango, Colorado

Timber Age Systems is a mass timber product company located in Durango, Colorado. Amidst challenges, like incidents of large-scale wildfires, rising housing prices, and a shortage of skilled labor, Timber Age Systems turned these challenges into opportunities by creating insulated, cross-laminated timber (CLT) modular panels that enable people to quickly assemble high-performance structures. Much of the labor necessary to build a modular CLT structure is done in a well-lit, climate-controlled manufacturing environment. This can lead to improved working conditions and high-skill labor employment (Colorado State Forest Service, n.d.).

There has been a forest health issue in the southern Rocky Mountain woods around Durango, as evidenced by two instances of significant wildfires, including the Missionary Ridge fire in 2002 and the "416" fire in 2018 (Colorado State Forest Service, n.d.). 56 homes were destroyed, and hundreds of acres were under danger during the Missionary Ridge fire (Colorado State Forest Service, n.d.). After these wildfires, it was crucial to restore forests to a state where they can sustain regular low-intensity fires, continue to provide building materials for regional economies, and still perform fully as forests if we are to have a chance at this landscape. The work done to mitigate wildfires is frequently contracted out to private companies, and the challenge posed by forest health has created opportunities for the forest product industry, as evidenced by the 11% increase in jobs in forest-related fields (Colorado State Forest Service, n.d.).

During forest thinning projects, unmerchantable wood is often burned, increasing the amount of carbon dioxide and particulate pollution released into the environment. Finding a use for some of the fiber harvested from trees and moving it into less wasteful endeavors is necessary. Timber Age Systems has accomplished turning forest wood waste into highly valuable building materials — instead of smoke (Colorado State Forest Service, n.d.).

Regarding the housing crisis, many Coloradans are unable to become first-time homeowners. Specifically, typical single-family home sale prices in Durango rose from $390,000 in 2018 to $675,000 in 2022 (Colorado State Forest Service, n.d.). However, modular and factory-built housing, which reduces the required labor force for installation could be a viable solution to provide more affordable housing (Colorado State Forest Service, n.d.).

Timber Age Systems was awarded a grant of $190,494 from USFS funding in 2024 with the proposal named “Ponderosa Pine Mass Timber Blueprints Enabling Local, High-Performance, Affordable, Attainable and Sustainable Off-Site Housing” procuring woods from San Juan National Forest (*Wood Innovations Program Grants*, n.d.).

- Golden West Pine Mills LLC in Ault, Colorado

Golden West Pine Mills LLC, a family-owned sawmill, uses technology to lower wildfire risk and produce mass timber products. Overly dense forests of small trees along the Front Range are increasing wildfire risk. When left on the landscape in large numbers, these dry trees ignite quickly, leading to large wildfires such as the Cameron Peak and East Troublesome Fires in 2020 (Colorado State Forest Service, n.d.-b). Kurt Mackes, a senior researcher scientist at Colorado State Forest Service, estimates that there are hundreds of thousands of acres that need to be treated in the Front Range, culminating at one point to 1.5 million acres (Colorado State Forest Service, n.d.-b). According to Mackes, some of these acres were "treated" by wildfires which were uncharacteristically severe. He suggested the idea of having a forest product facility along the Front Range that would be able to pay the full value of getting those small trees off the landscape (Colorado State Forest Service, n.d.-b).

Golden West Pine Mills thus tries to use small-diameter wood, with a diameter of 6 to 12 inches, which has historically proven to be a difficult size to utilize. More precisely, it uses Douglas-fir, lodgepole pine, and ponderosa pine from the northern Colorado Front Range that is both green standing and beetle killed. The fact that it can also use charred wood from a forest fire if it has not been severely damaged is a significant and distinctive feature (Colorado State Forest Service, n.d.-b).

Grants have been awarded to Golden West Pine Mills to enlarge its conventional sawmill and incorporate a radio-frequency technology process. During the 1990s, it manufactured kitchen cabinets and later transitioned to producing more architectural millwork goods. However, Andy Hinz, the owner of the company, came across an article in 2014 from the U.S. Forest Services Forest Products Lab that predicted a significant decrease in the use of lumber for wide-width purposes and developed a brand-new procedure known as EGAR (Colorado State Forest Service, n.d.-b). The method known as Edge, Glue, and Rip, or EGAR, produces boards from small-diameter timber. Small wood is cut into components, which are glued into a panel before being cut again into the preferred lumber width. Its newly acquired machine can use hydraulic pressure to securely glue and clamp materials up from edge to edge while a radio frequency flows through the bottom plate to the top plate to cure a panel in 120 seconds (Colorado State Forest Service, n.d.-b). If this process was done manually, one to two panels per day can be produced. This innovative machine is a game changer in productivity (Colorado State Forest Service, n.d.-b).

According to preliminary testing, EGAR products are stronger, flatter, and straighter than conventional solid sawn materials, and they are intended to be utilized for construction grade lumber (Colorado State Forest Service, n.d.-b). It can be used for a wide range of

different purposes, including shiplap paneling, tongue and groove paneling, backboards, architectural panels, panels for cabinetry projects, and display-type products. Additionally, it was discovered that these EGAR products can be utilized in the building of cross-laminated timber (CLT) through collaboration with the Colorado State University Civil Engineering Test Lab. This business has received grant support through the U.S. Forest Service Community Wood Innovation Program. Golden West Pine Mills was awarded $933,325 in 2024 with a proposal titled “Increasing Mill Capacity for Existing EGAR/Mass Timber Manufacturing Facility” (*Wood Innovations Program Grants*, n.d.). Golden West Pine Mills was also nominated for Partner of the Year because of its innovative work that can help U.S. Forest Service to take an underutilized resource and turn it into a value-added product (Colorado State Forest Service, n.d.-b).

6.2 Carbon Sequestration: Charm Industrial

Charm Industrial (Charm) collects forestry and agricultural residues, uses its pyrolysis systems to convert biomass into bio-oil in a self-sustaining reaction, transports carbon-rich bio-oil to an injection well site, and pumps the bio-oil underground where it sinks and solidifies in place. As of Aug. 14, 2024, it has permanently removed a total of 7,183 tons of carbon dioxide from the atmosphere, out of reach of wildfires, soil erosion, and land use change (Bejamas, n.d.). This removal of carbon dioxide can allow the certification of carbon credits to sell to those companies that want to demonstrate to customers, investors, and employees that they take their climate leadership and responsibility seriously. The head of sustainability at Shopify, Stacy Kauk, mentioned that “there is a huge brand and soft capital benefit to buying carbon removal credit, rather than an avoidance or a REDD+ (reducing emissions from deforestation and degradation in developing countries) credit” (Clancy & Clancy, 2024).

A consortium of Frontier Climate buyers from Google, Stripe, Facebook, McKinsey, Shopify, H&M, Autodesk, Workday, and Watershed inked $53 million offtake agreements with Charm Industrial in 2023 (*Charm Industrial*, n.d.). The deals included 112,003 contracted tons with a delivery date of 2024–2030. Between 2024 and 2030, the price per ton of carbon sequestration can decrease by at least 37% up to 75% depending on Charm's current scaling plans and the possibility of increased government incentives (*Charm Industrial*, n.d.). This agreement guarantees not only the removal of carbon dioxide but also measuring, reporting, and verifying (MRV) that every ton is kept permanently and safely.

Biomass waste and leftovers are broken down into three products via a process called pyrolysis, which involves heating them to high temperatures in an oxygen-free environment: syngas, biochar, and carbon-rich bio-oil (*Charm Industrial*, n.d.). The pyrolysis systems, pyrolyzers, are operated by the resultant syngas. Biochar can be applied to fields

for agronomic benefits. The bio-oil is injected into EPA-regulated wells, where it settles and solidifies to provide permanent carbon removal while retaining a large portion of the carbon from the original biomass. BiCRs, or biomass carbon removal and storage, present a viable way to remove carbon at scale at a cheap cost (*Charm Industrial*, n.d.).

Charm's modular strategy turns waste biomass into bio-oil anywhere waste biomass is available by using compact, portable pyrolyzers. Pyrolyzers made by Charm are transportable, just like other farm equipment, and can be carried from farm to farm on the bed of a truck. Charm can then transport bio-oil — 5-7 times denser than the initial raw biomass thanks to on-site pyrolysis (*Charm Industrial*, n.d.). Crucially, Charm Industrial uses biomass feedstocks (corn stover and forest management waste) that are abundant and readily classified as waste.

Charm's approach to carbon sequestration has limitations when it comes to large-scale carbon dioxide removal. For instance, (1) will it be better to use waste biomass for pyrolysis to bio-oil sequestration and (2) will the marginal ton of waste biomass still be net-carbon-negative at large scales? Since other methods of carbon sequestration will also encounter difficulties at these mass volumes, a portfolio of approaches is required as a combination of wind, solar, geothermal, and nuclear power is expected to provide renewable energy at scale (*Charm Industrial*, n.d.).

6.3 Biochar Now

Biochar Now is a pioneer of producing high-quality biochar on a massive scale in the biochar sector. In November 2011, Biochar Now was incorporated with three main objectives in mind: 1. Recognize the advantages of biochar and its prospective uses 2. Recognize how to reliably produce high-quality biochar on a massive scale. 3. Comply with EPA emission regulations (*About*, 2019). Thus far, Biochar Now has granted eleven patents related to technology and biochar uses (*About*, 2019).

Biochar is highly adsorbent and a specially made charcoal that was first used as a soil amendment. The first known use of biochar occurred thousands of years ago in the Amazon Basin, when large areas of terra preta—a dark, extremely productive soil—were found, displaying significant concentrations of both organic matter and biochar (*What Is Biochar?*, 2019). Like charcoal, biochar is made by heating biomass, or wood or other plant material, with little to no oxygen. But unlike charcoal, which is frequently used for cooking worldwide, biochar is produced under precise instructions with the purpose of applying it to soil to improve agricultural harvests and soil fertility as well as sequester carbon to mitigate global warming. Other market uses of biochar are being discovered regularly as universities and large industrial partners conduct extensive research into this versatile material and its

cation exchange properties. Biochar is thought to be the key component in a carbon-negative strategy to resolve critical current ecological challenges (*What Is Biochar?*, 2019).

Specialty agriculture, land reclamation, oil and gas, odor control, bio-filler, and algae removal are among the applications for biochar. Research shows that biochar-enriched soils produce bigger, healthier plants with higher yields in specialized agriculture that produces high-value crops, especially in degraded or severely weathered soils (*Applications*, 2019). It is argued by Biochar Now users that biochar expenses are covered by higher yield profits in the first year. The outstanding absorption and stability of biochar is the reason behind an increase in soil fertility. Biochar is even more efficient at keeping nutrients and making them available to plants than other organic soil additions (*Applications*, 2019). Its porous structure draws in beneficial microorganisms, maintains nutrients, and stores moisture, improving crop output and fertilizer efficiency and decreasing irrigation requirements. Furthermore, compared to other organic matter forms, biochar is far more stable in the environment. In locations with depleted soil, low organic resources, and little water, this potent soil amendment can be an important tool to promote food security and crop diversity. The usage of biochar may boost agricultural output and soil fertility, which could reduce the demand for more deforestation for farming (*Applications*, 2019).

When it comes to land reclamation, biochar is an affordable way to bind pollutants and stop them from seeping into surface and ground water (*Applications*, 2019). Plus, previously inert soil is now suitable for plant growth. Biochar stops the toxins from leaking into nearby water sources by trapping the heavy metals in the soil around closed mining. Secondarily, with better soil fertility and less erosion, biochar promotes the regrowth of flora on this challenging terrain. Furthermore, the cost of using biochar to complete mine reclamation is far lower than that of transporting tailings to landfills for hazardous waste (*Applications*, 2019). Biochar tests at closed mine sites in Colorado and other western states provide evidence of biochar's potential for mine recovery. The operations restored the land to vegetation in less than a year, significantly lowering the possibility of heavy metals seeping into water sources (*Applications*, 2019).

The oil and gas sectors are using biochar as an affordable way to abide by the air and water quality standards set out by the Environmental Protection Agency (EPA) in the United States. Biochar is applied at oil and gas producing locations to decontaminate the soil to comply during drilling operations. In doing so, the hydrocarbons and volatile organic compounds (VOCs) are drawn into the biochar, where they are degraded by embedded bacteria to a non-toxic state. Currently, produced water from wells is purified using biochar filtering process (*Applications*, 2019). In this application, biochar eliminates impurities so that clean water can be released.

Black carbon (i.e., charcoal/biochar) has been utilized for filtration and odor control throughout human history for its adsorptive qualities (*Applications*, 2019). Thus, it makes sense that odors, organic nutrients, and environmental pollutants would be absorbed and retained by carbon-rich biochar due to its porous nature. Because of these qualities, biochar has been applied to a variety of materials, including compost, manure, landfills, and foul-smelling waterways (*Applications*, 2019).

Biochar can be used as a carbon-negative bio-filler for the asphalt, concrete, and plastic industries. It has been demonstrated that using biochar in bio-fillers can reduce weight while providing an affordable option for various sectors. Biochar-based polymers have demonstrated enhanced strength and improved performance at high temperatures (*Applications*, 2019). Using biochar can help lessen industry reliance on fossil hydrocarbon intensive materials and methods (*Applications*, 2019).

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8. Appendices

8.1 Method for Economic Impact Analysis

Data and method for this analysis starts from social accounting matrix (SAM) which connects total aggregate demand and supply for an entire economy consisting of every industry sector, endogenous institutions within a region such as households, and exogenous entities to a region such as domestic and foreign trade, federal government, and state/local government. Data from regional social accounts can be transformed into a regional SAM.

> "A SAM is a statistical framework that utilizes double-entry bookkeeping to trace all monetary flows within a regional economy over a given period. Mathematically, a SAM is a square matrix in which each nonzero element records the value of a financial transaction between economic actors" ("THE 2019 FOREST REPORT," 2019, p.76).

Table A1 presents a notational, three-sector SAM for a hypothetical economy. Practically, the regional SAM of Colorado in 2022 is exported from IMPLAN software.

Table A 1. Notational social accounting matrix (SAM) for a three-sector regional economy

		Local Industries			Local Households (Consumption)	Exogenous Demand (exports)	Total
		I1	I2	I3			
Local Industries	1	z_{11}	z_{12}	z_{13}	c_{14}	y_1	x_1
	2	z_{21}	z_{22}	z_{23}	c_{24}	y_2	x_2
	3	z_{31}	z_{32}	z_{33}	c_{34}	y_3	x_3
Local Households (value added)		v_1	v_2	v_3		$y_4=v_4$	v
Exogenous Inputs (Imports)		m_1	m_2	m_3	m_4		m
Total		x_1	x_2	x_3	c	y	

Notes: "Exogenous demand" is defined as any sales outside the region. SAMs present sales between the accounts across a row and purchases between accounts down a column. By definition, $c = v$ and $y = m$.

> "Industry rows record sales to all possible endogenous (i.e., local) and exogenous outlets including endogenous intermediate demand (z_{ij}); endogenous final demand associated with household spending (c_{i4}); and exogenous final demand

associated with, for example, household investment income, government spending, and exports (y_i). The total of these transactions represents the total industry output of a given sector (x_i). Note that total consumption (c_{i4}) is equal to total income (v_{4j}) and that y_4 and v_4 are identical and can be interpreted as both an export and income. Industry columns record purchases and represent Leontief production functions that include local input purchases (z_{ij}), factor payments (income; v_{4j}) and imported input purchases (m_{5j}). Within the SAM accounting framework, economic actors are required to meet their budget constraints to maintain equilibrium between buyers and sellers. Thus, all row sums are balanced with corresponding column sums" ("THE 2019 FOREST REPORT," 2019, p.76-77).

Based on a regional SAM, the first step is to extract endogenous sector by endogenous sector matrix. Then, every element in this matrix should be divided by each column sum which is the same with each row sum, output of an industry sector. The result should look like Table A2.

Table A 2. Endogenous requirement matrix (A) of a regional economy

		Local Industries			Local Households
		I1	I2	I3	
Local Industries	I1	a_{11}	a_{12}	a_{13}	a_{14}
	I2	a_{21}	a_{22}	a_{23}	a_{24}
	I3	a_{31}	a_{32}	a_{33}	a_{34}
Local Households		a_{41}	a_{42}	a_{43}	

a_{ij} equals the share of jth industry's input purchase from ith industry over jth industry's total outlay and the full dimension matrix of a_{ij} coefficients is denoted as matrix **A**. Matrix A represents the matrix of technical coefficients based on a fixed Leontief production function throughout each industry, meaning "how much of each dollar of output goes into purchasing inputs from other local sectors in the economy" ("THE 2019 FOREST REPORT," 2019, p.77). This technical coefficient is important in that it represents how much each industry keeps money within a regional economy.

Based on matrix A, the output of an economy can be expressed in equation 1.

$$X = AX + Y \cdots\cdots equation\ (1)$$

Where X represents a vector of industry outputs, A is the matrix of technical coefficients, and Y is a vector of exogenous final demands. This input-output matrix can be interpreted as both where a sector sells its output and where a sector buys its input. The term AX

represents the total amount of output a given sector sells locally. Thus, equation 1 can be understood as all output of a given sector must either be sold locally (AX) or exported out of the region (Y).

$$(I - A)X = Y \cdots\cdots equation\ (2)$$

By rearranging equation 1, equation 2 can be obtained where I is an identity matrix of ones along the diagonal and zeros in the off diagonal cells. When we solve for X, equation 3 is drawn, the fundamental equation of input/output analysis. $(I - A)^{-1}$ is considered as multiplier, and every industry output (X) is interpreted as the multiplication between multipliers ($(I - A)^{-1}$) and final demands (Y).

$$X = (I - A)^{-1}Y \cdots\cdots equation\ (3)$$

The economic impact analysis of the USDA Wood Innovation Program Grants used a variation of equation 3 by assigning each grant to a relevant sector in the vector of Y with zeros otherwise, interpreting these grants from the federal institution as changes in exogenous final demand on the forest product industry, and the multiplication between the multipliers ($(I - A)^{-1}$) and a modified vector Y with only grants entries gives us ex-ante estimated economic impact of creating economic activities in every industry sector by the grants. Table A3 shows the modified Y vector with public grants assigned as the column of "Change in Final Demand" and the result of multiplication between the multipliers ($(I - A)^{-1}$) and a modified vector Y as the column of "IMPACT"

Table A 3. Modified Y vector (Change in Final Demand) with public grants assigned and IMPACT column because of multiplication between $(I - A)^{-1}$ and modified Y vector

Industry Sector in 3-digit NAICS	Change in Final Demand		IMPACT
111 - Crop Production	$0		$36,107
112 - Animal Production and Aquaculture	$0		$63,601
113 - Forestry and Logging	$314,000	Eagle Wood Cutting and Processing, KFB forestry, Route Millworks	$359,737
114 - Fishing, Hunting and Trapping	$0		$488
115 - Support Activities for Agriculture and Forestry	$1,050,000	Biochar Now, Lignum Support	$1,076,146
211 - Oil and Gas Extraction	$0		$215,118
212 - Mining (except Oil and Gas)	$0		$23,860
213 - Support Activities for Mining	$0		$75,669
221 - Utilities	$600,000	EcoTech Biofuels, Yosemite Clean Energy	$921,806
23 - Construction	$0		$123,378
311 - Food Manufacturing	$0		$150,071
312 - Beverage and Tobacco Product Manufacturing	$0		$35,452
313 - Textile Mills	$0		$341
314 - Textile Product Mills	$0		$2,680
315 - Apparel Manufacturing	$0		$2,082
316 - Leather and Allied Product Manufacturing	$0		$413
321 - Wood Product Manufacturing	$1,703,000	Golden West Pine Mill, Colorado School of Mines, Redstone Timber Frames, Timber Age Builders	$1,901,492

8.2 Method for Economic Contribution Analysis

Waters, Holland, and Weber (1999) suggested formally a modification to the standard Leontief input-output model that increases the amount of useful information produced. This modification is constructing a diagonal matrix with final demand on each industry sector along the diagonal line of $n \times n$ matrix, $\hat{Y}$. Then, $n \times n$ multiplier matrix ($(I - A)^{-1}$) is multiplied by an $n \times n$ diagonal matrix of final demand ($\hat{Y}$) and yield an $n \times n$ matrix of gross and base output (X), which can be expressed mathematically as the equation 4:

$$X = (I - A)^{-1} * \hat{Y} \cdots \cdots equation\ (4)$$

" $(I - A)^{-1}$ represents an $n \times n$ matrix of interactions between the endogenous sectors of the economy and is also called the "Leontief inverse." This Leontief inverse can also be thought of as a matrix of partial output multipliers, where the column sum of the endogenous sector columns through the output producing sector rows is the

output multiplier for each respective sector." ("THE 2019 FOREST REPORT," 2019, p.79).

The resulting $n \times n$ output matrix (X) as a square matrix can separate each industry's export-base contribution as a row vector of column sums from gross contribution as a column vector of row sums and ensure the sum of export-base contributions of all industry sectors is equal to the sum of gross contribution of all industry sectors, total industry output.

Base contributions in terms of employment and value-added are obtained by constructing vectors of employment over output ratio and value-added over output ratio for each industry sector respectively, based on the industry detail of Colorado in 2022 exported from IMPLAN software, and multiplying X output matrix with each of employment over output ratio vector and value-added over output ratio vector. The results of the multiplication give the base contribution of each industry sector in employment and value-added, respectively.