2024 Forest Bioeconomy Landscape Study

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Introduction

The forest bioeconomy uses forest biomass from sustainably managed forests to make bioproducts. Foresight has published a paper – 'VENTURES TO VALUE CHAINS - FOREST BIOECONOMY' describing value chain of forest bioeconomy (snapshot of value chain is provided in next slide). Based on the value chain, the report has been divided into below three modules:

- **Module A - Sustainable Forest Management**
- **Module B - 'Sustainable Bioprocessing'**
- **Module C - 'Value-Added Products/Materials/Applications'**

This report analyses the worldwide patent landscape for the above three modules in the forest bioeconomy sector. More specifically, patent publications disclosing sustainable techniques for forest management, forest harvesting operations, Bioprocessing, etc. are studied in detail, in this report. Further, market insights including key mergers & acquisitions, Key partnerships, key investments, key market players, etc. have been provided.

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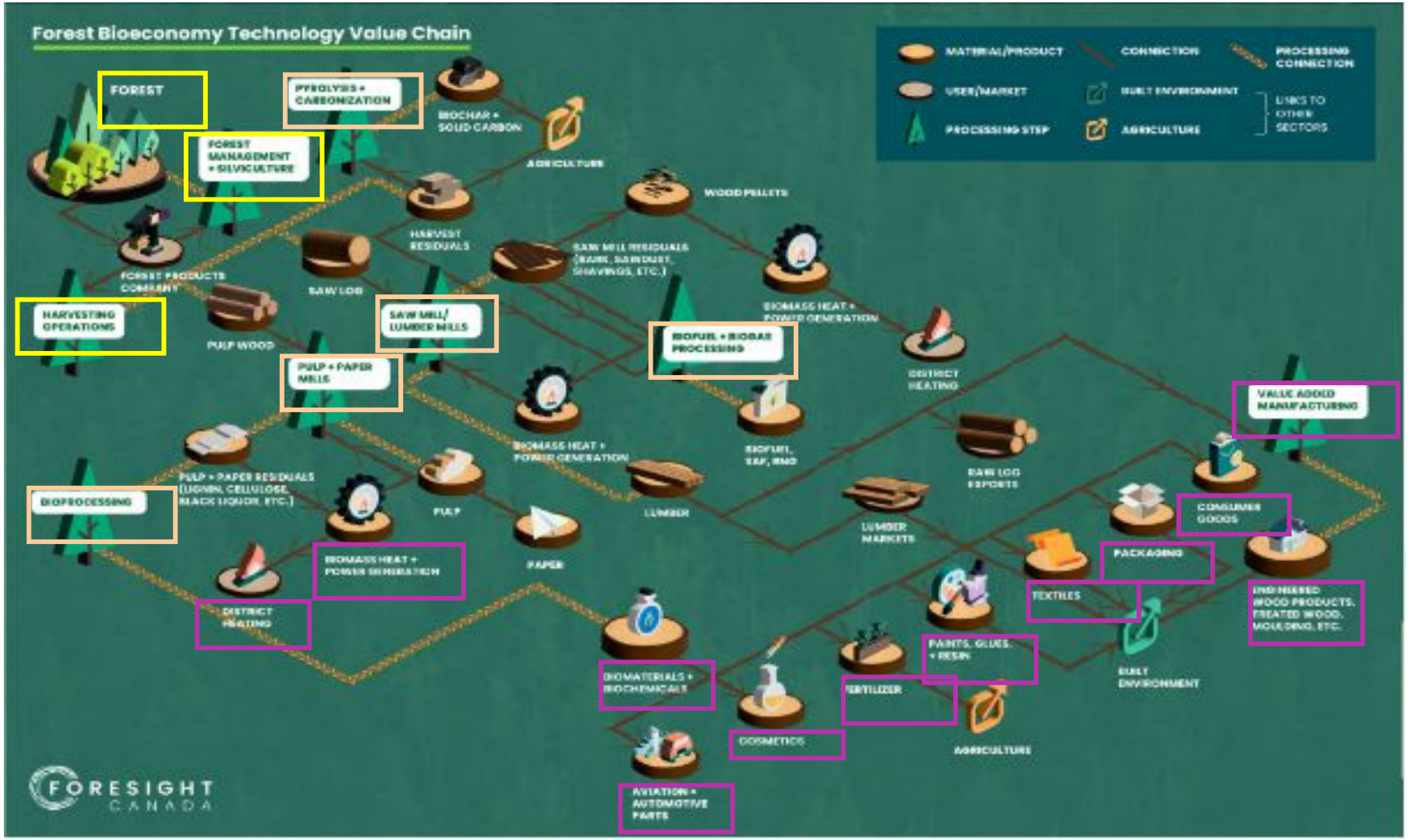
Forest Bioeconomy- Value Chain (1/2)



Module A: Sustainable Forest Management

Module B: Sustainable Processing

Module C: Value-Added Products/Materials/Applications

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Module A: Sustainable Forest Management

Sustainable forest management refers to the practice of managing forests in a way that balances environmental, social, and economic considerations. It includes concepts related to forest monitoring, forest harvesting techniques, and reforestation techniques.

Module B: Sustainable Processing

Sustainable processing involves the conversion of biomass and waste from forests into useful products. The objective is to create economically viable products while minimizing environmental impact and promote resource efficiency. This includes processes in paper and pulp mills, saw-mills, bioprocesses to convert biomass, methods to manufacture engineered wood products.

Module C: Value-Added Products/ Materials/Applications

Bioproducts are derived from forest biomass that offer additional benefits or features beyond their basic functions, such as enhanced performance, durability, or sustainability. It includes ways to utilize the residues of traditional forestry companies like lumber, pulp, and paper mills, for the purpose of creating value-added products, such as engineered wood products, biofuels, biochemicals, biomaterials, and more.

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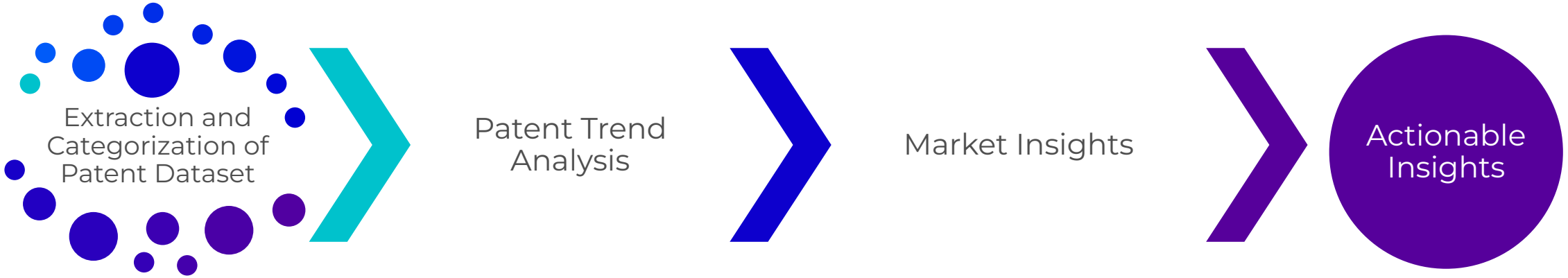
Methodology

The methodology used in the report involved categorization of patent applications under multiple nodes of taxonomy and extracting useful insights from the categorized patent dataset. Further, performing market analysis to recommend actionable insights for Canada-based companies. The methodology includes following steps:



Step 1: Used various search strategies (keywords, classes, citations, semantic and similarity) to identify the global active assets relevant to the technology.

Step 2: Presented insights through different charts and graphs for the patent dataset.
It includes:
Technology/Sub-Technology based trends, Assignee based trends, Geography based trends, Filing vs. Grant trends, etc.

Step 3: Identified Key market players, Key mergers & acquisitions, Key partnerships, Key investments, Emerging Technologies, Government Policies and Initiatives, Relevant Standards and Standard Essential Patents, etc.

Step 4: Recommended Actionable insights, performed Whitespace Analysis and identified Opportunity areas.

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Technology Taxonomy

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TECHNOLOGY TAXONOMY
Module A— ‘Sustainable Forest Management’

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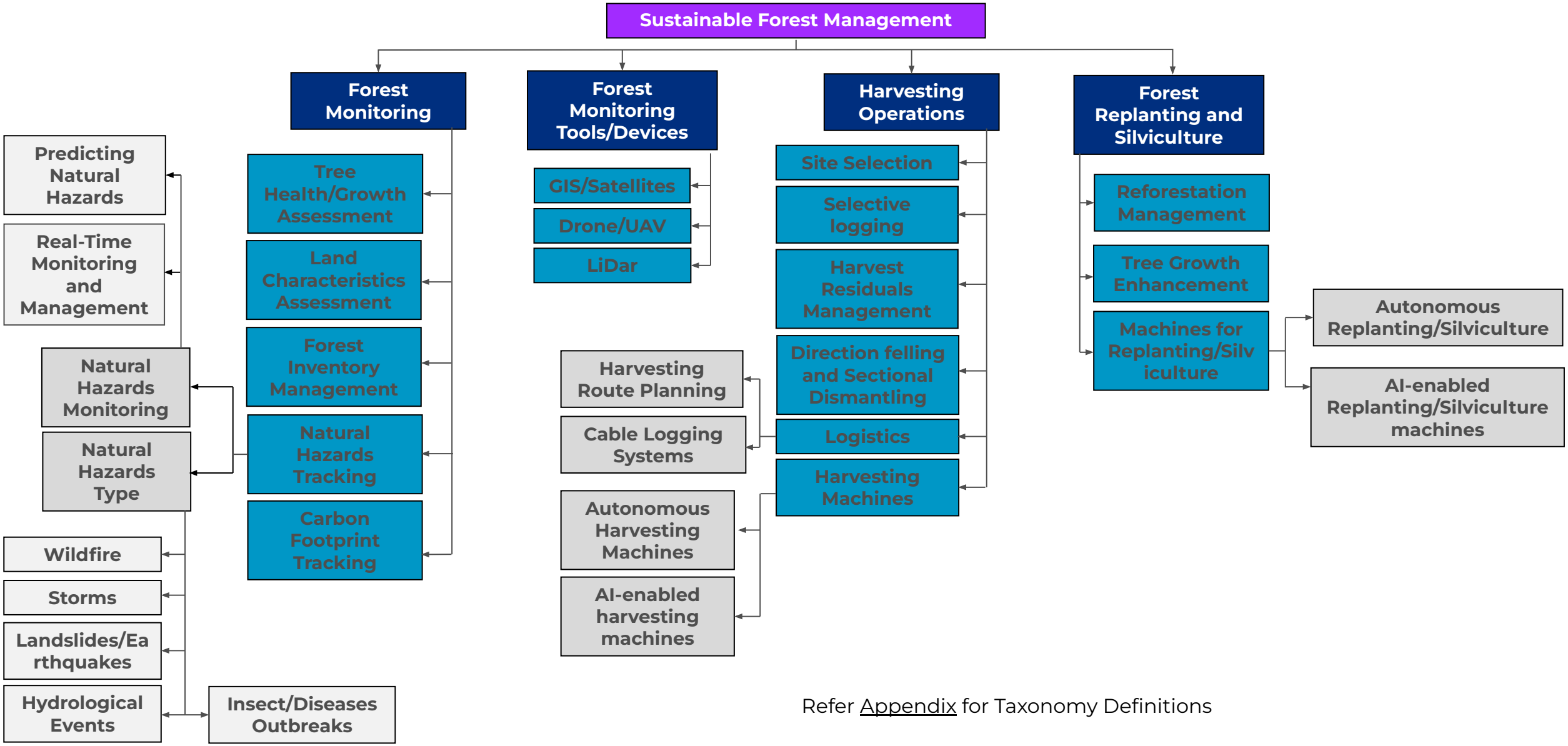
Technology Taxonomy – Module A – ‘Sustainable Forest Management’



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TECHNOLOGY TAXONOMY
Module B— ‘Sustainable Bioprocessing’

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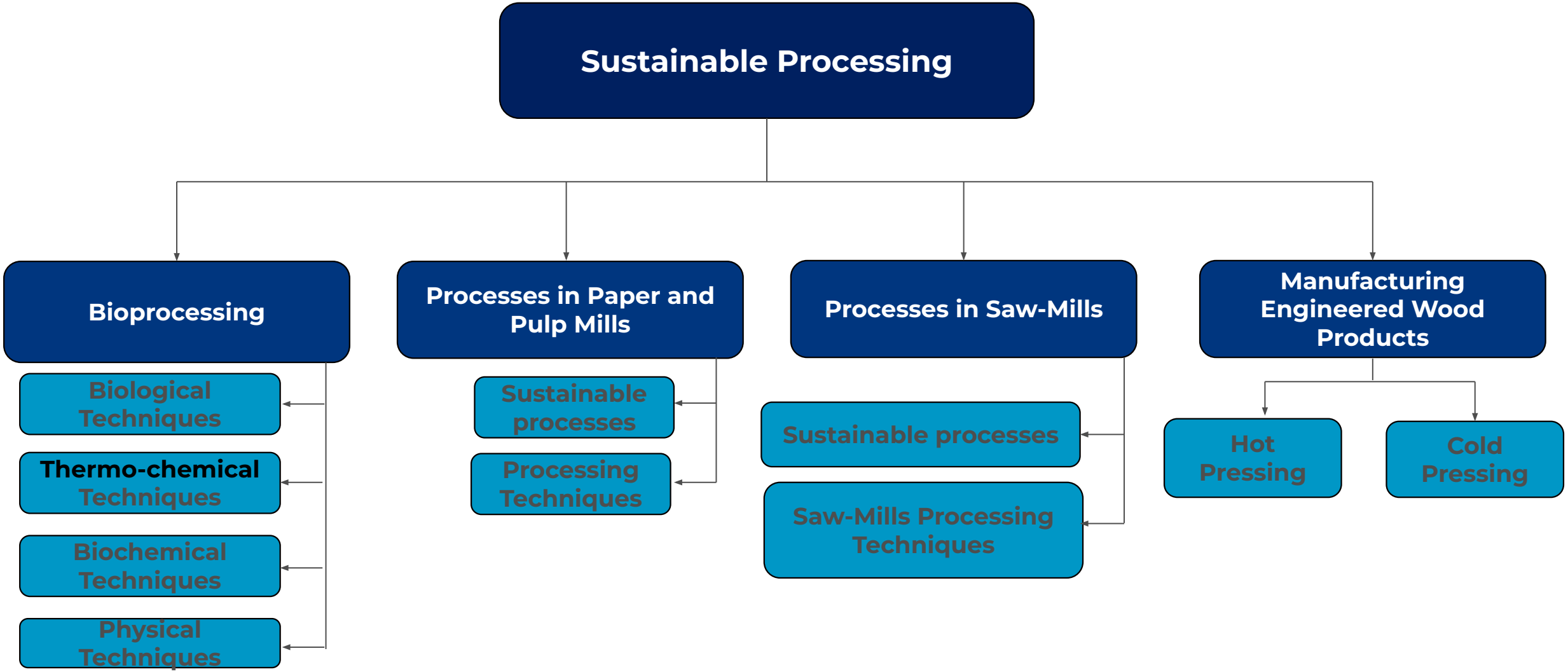
Technology Taxonomy – Module B – 'Sustainable Bioprocessing'



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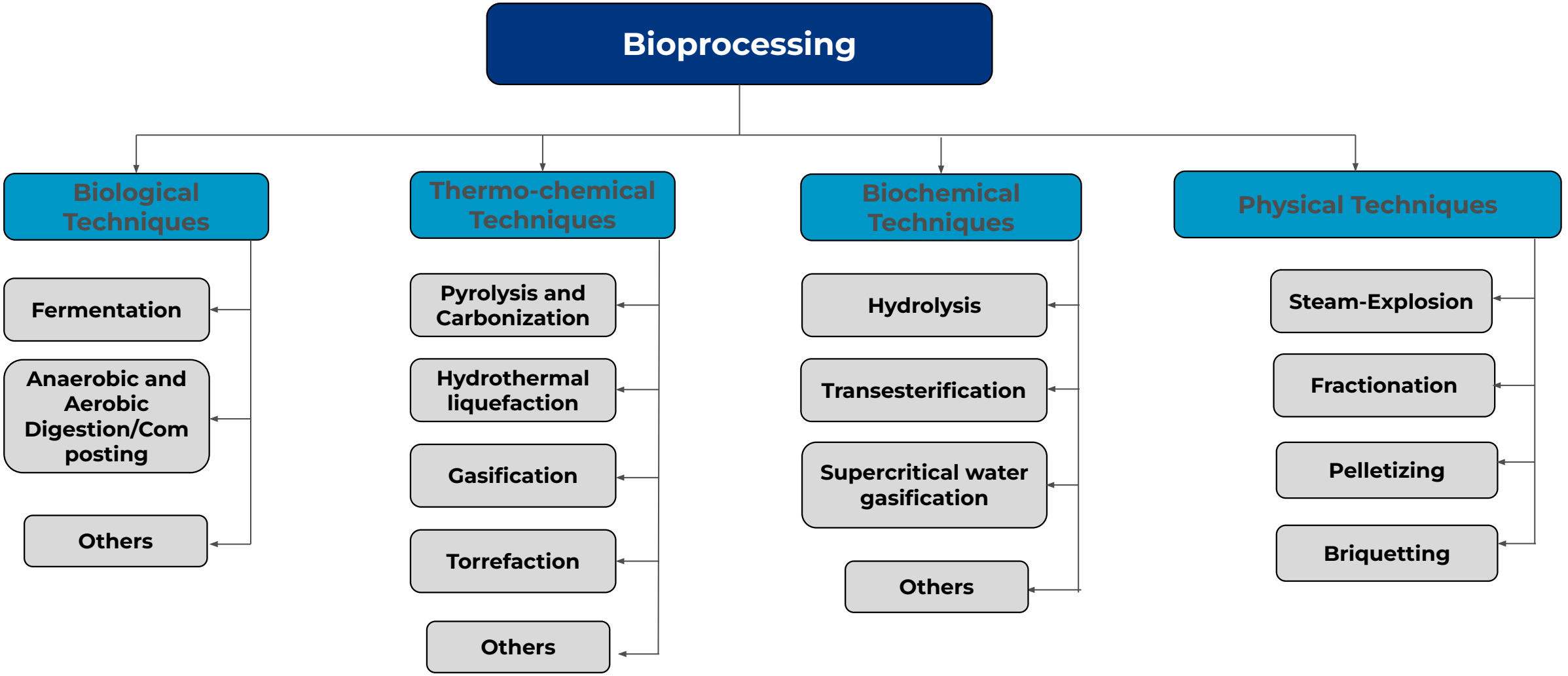
Technology Taxonomy – Module B – ‘Sustainable Bioprocessing’



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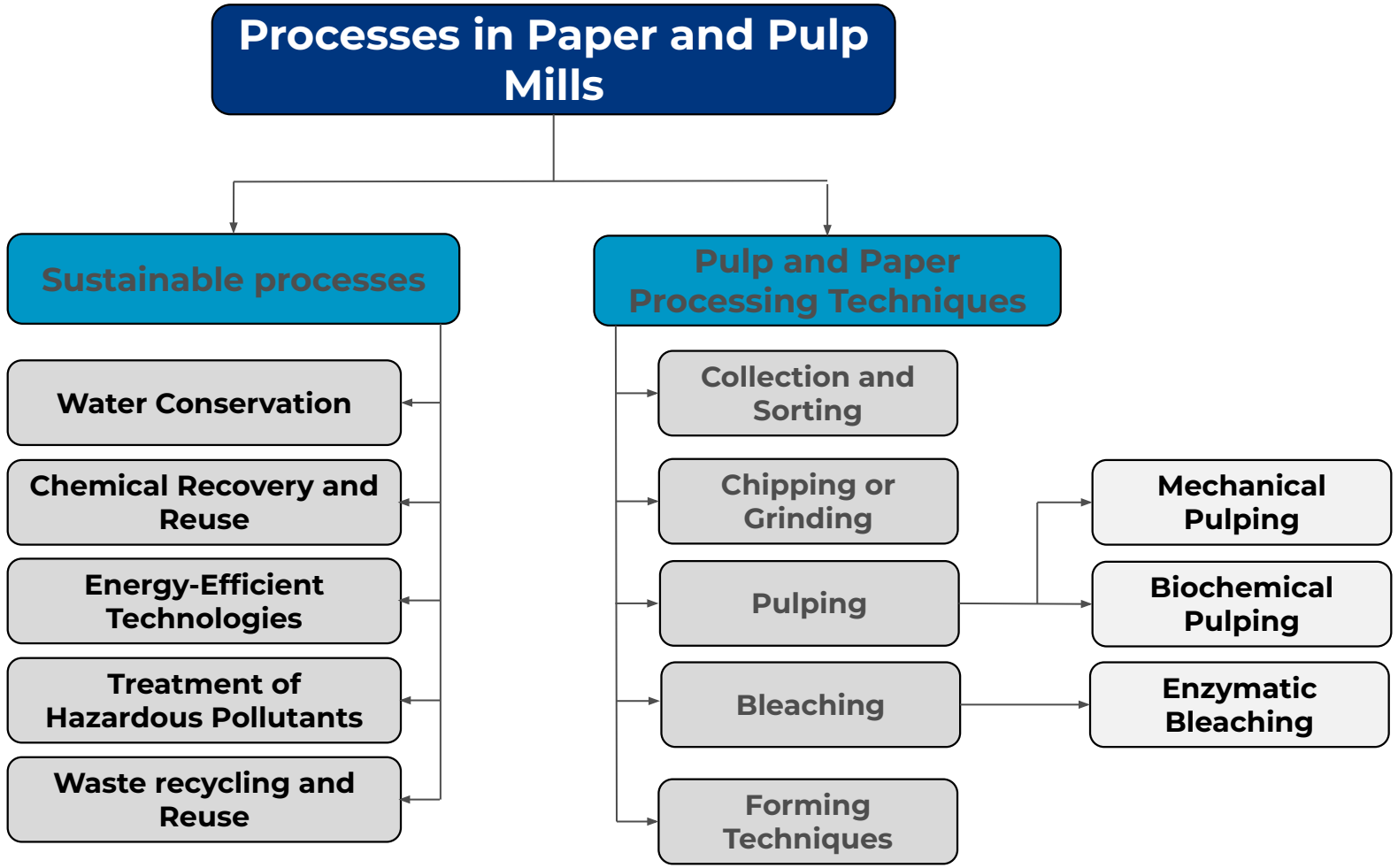

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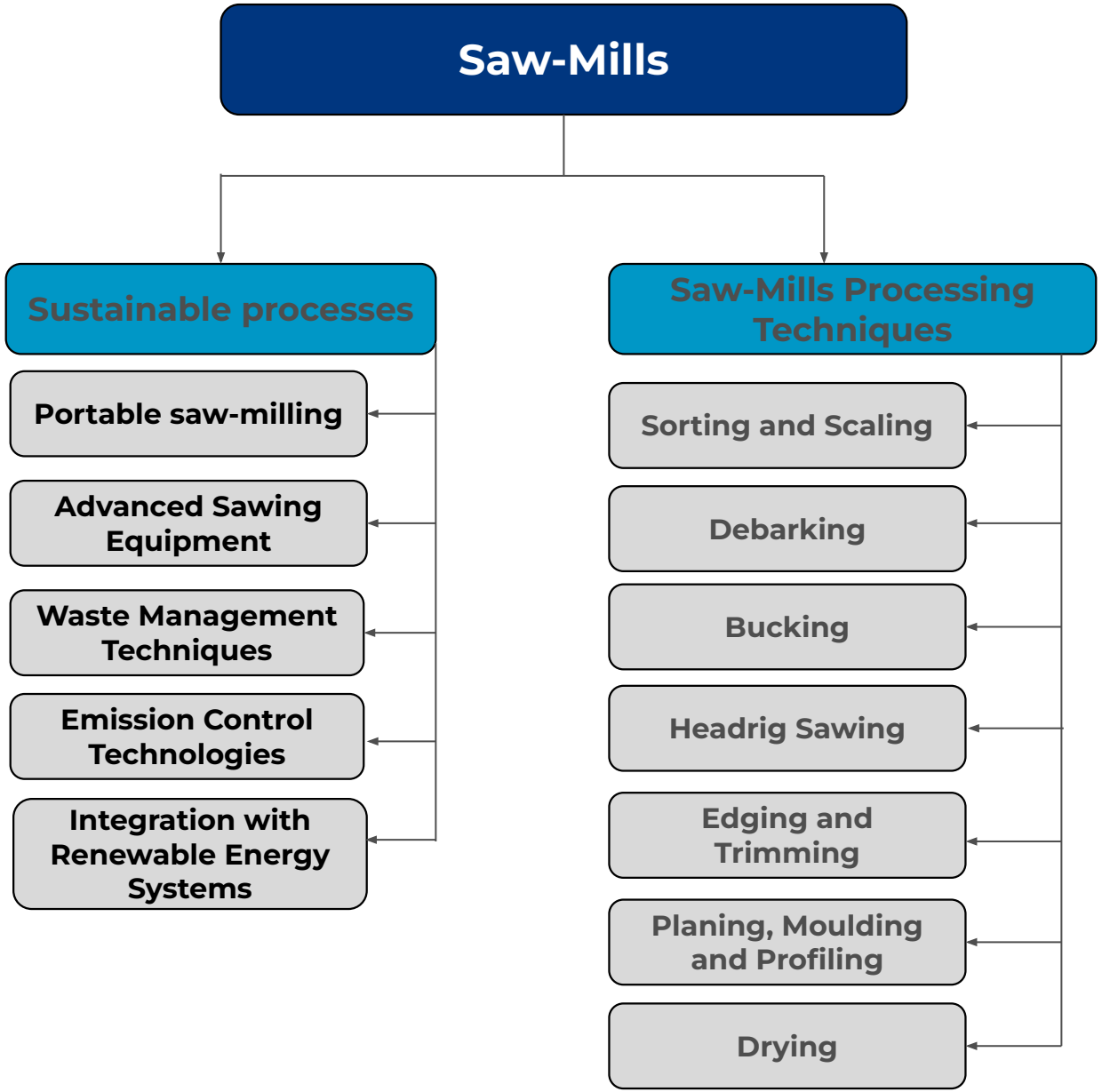

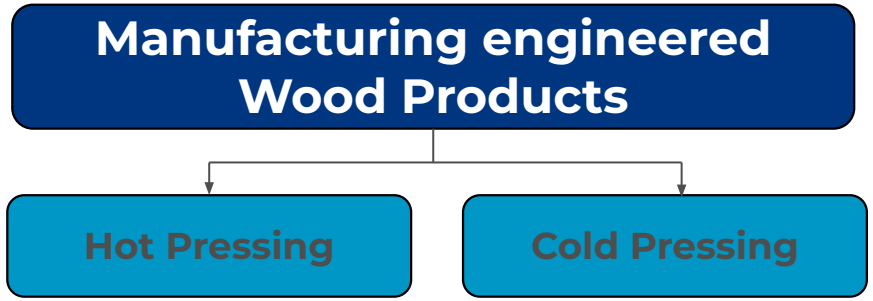

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TECHNOLOGY TAXONOMY

Module C— ‘Value-Added Products/ Materials/ Applications’

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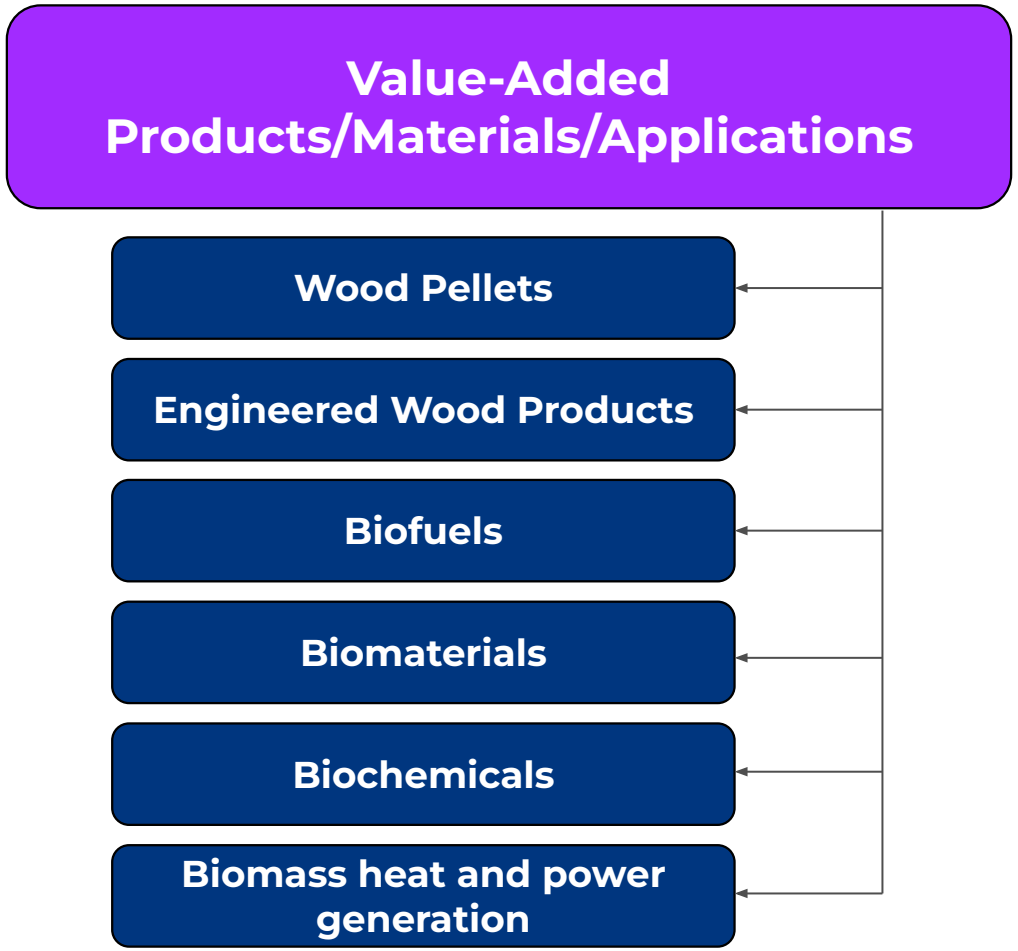
Technology Taxonomy – Module C – 'Value-Added Products/ Materials/ Applications'



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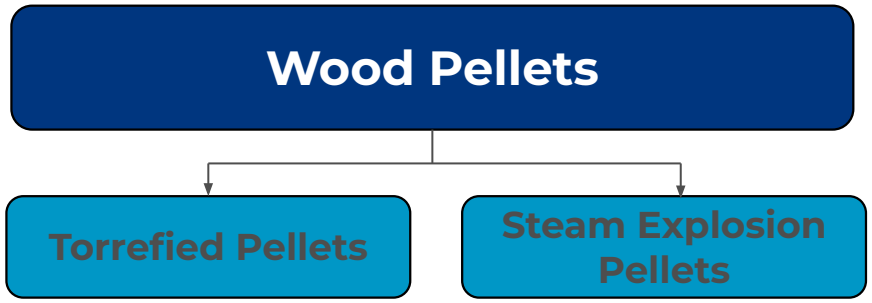
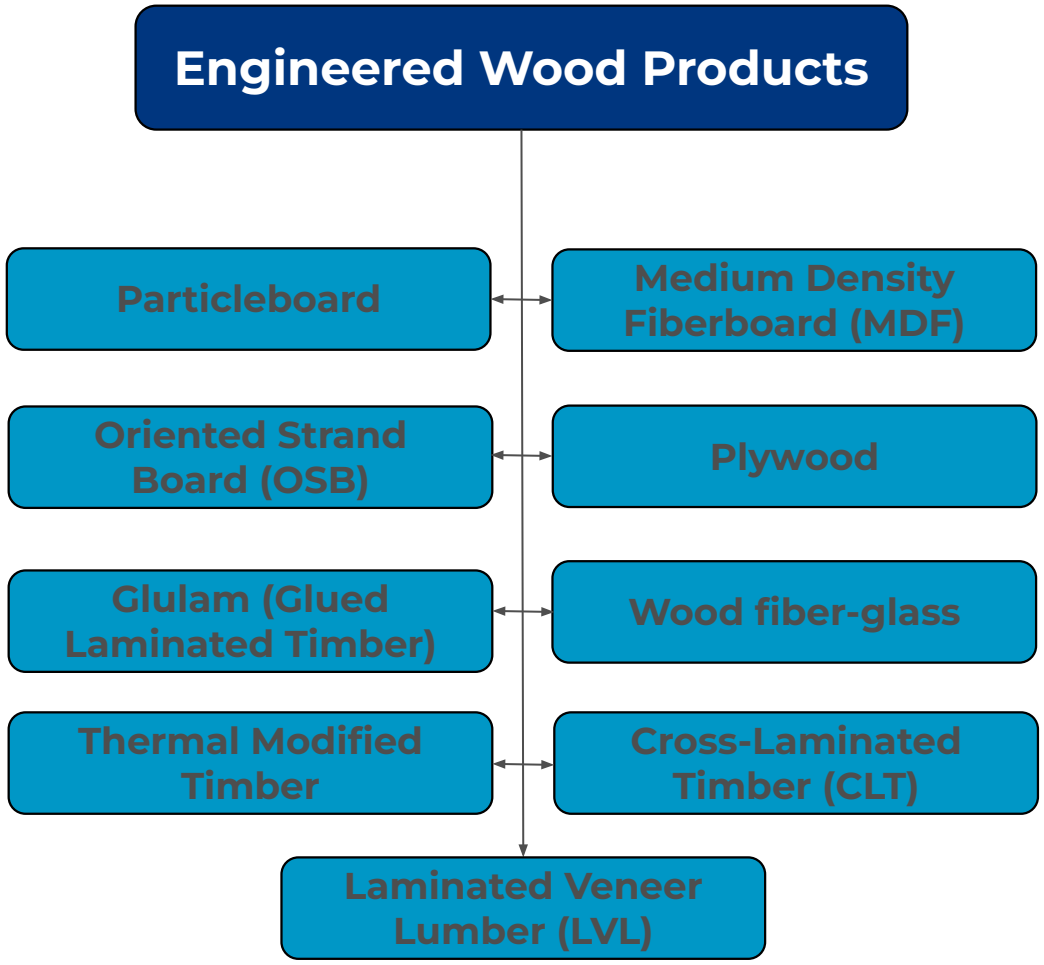
Technology Taxonomy – Module C – 'Value-Added Products/ Materials/ Applications'





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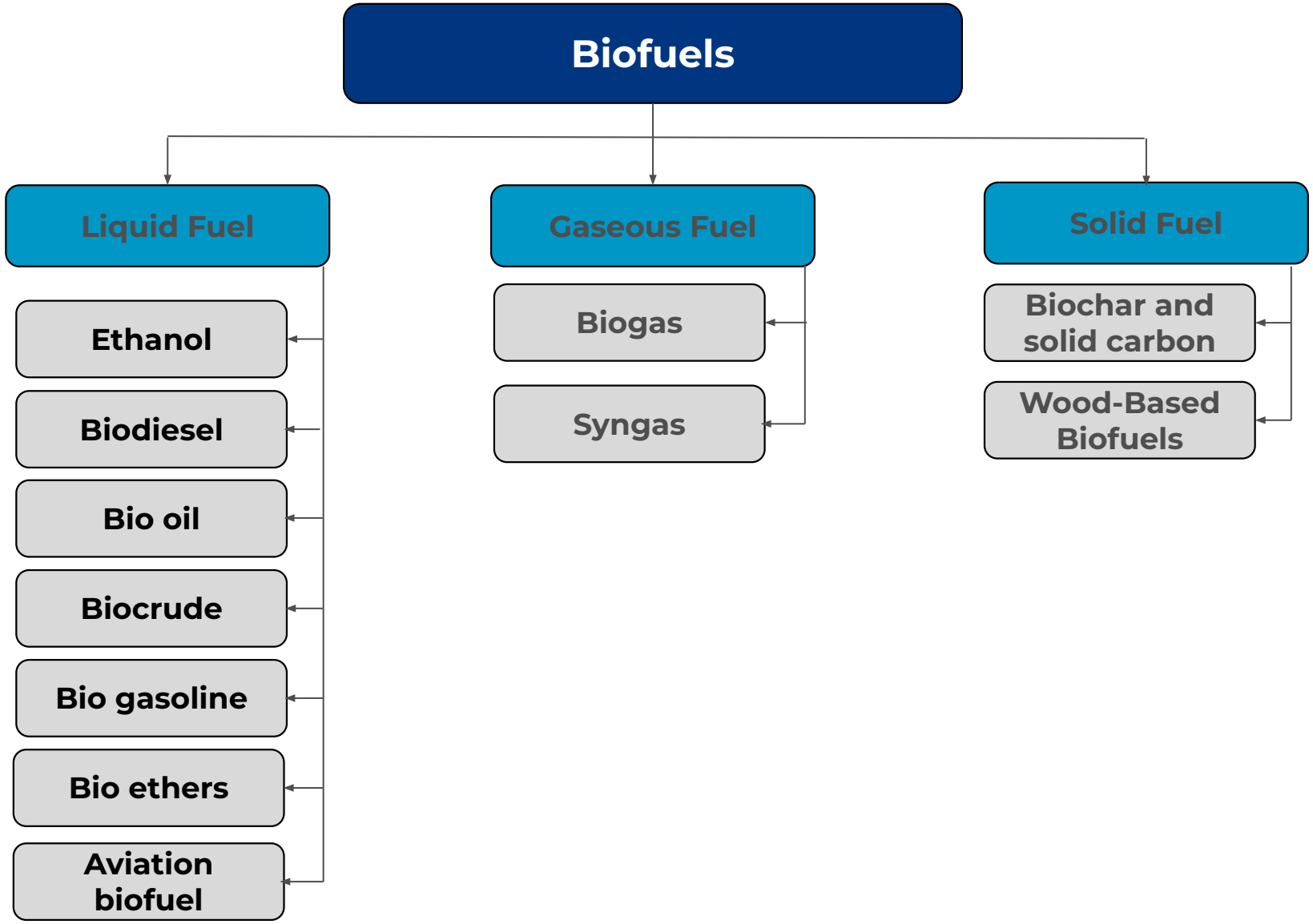
Technology Taxonomy – Module C – 'Value-Added Products/ Materials/ Applications'



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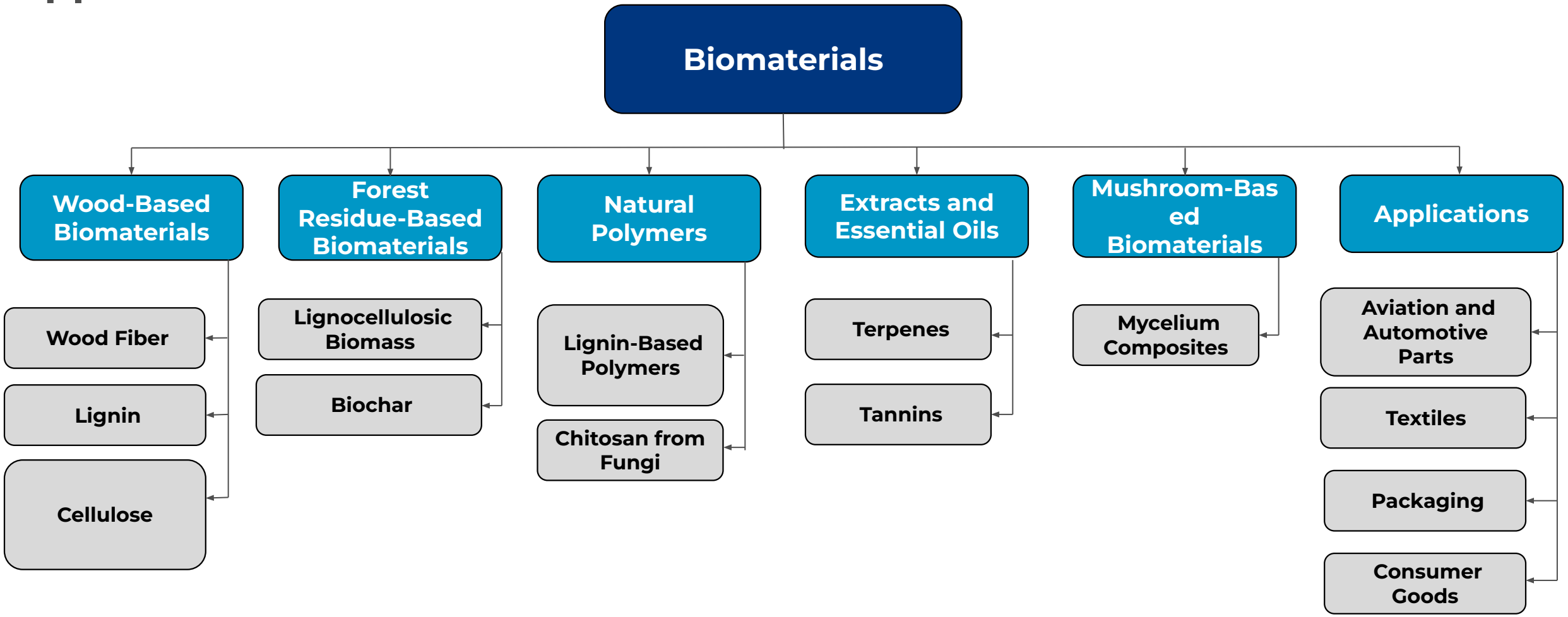
Technology Taxonomy – Module C – 'Value-Added Products/ Materials/ Applications'



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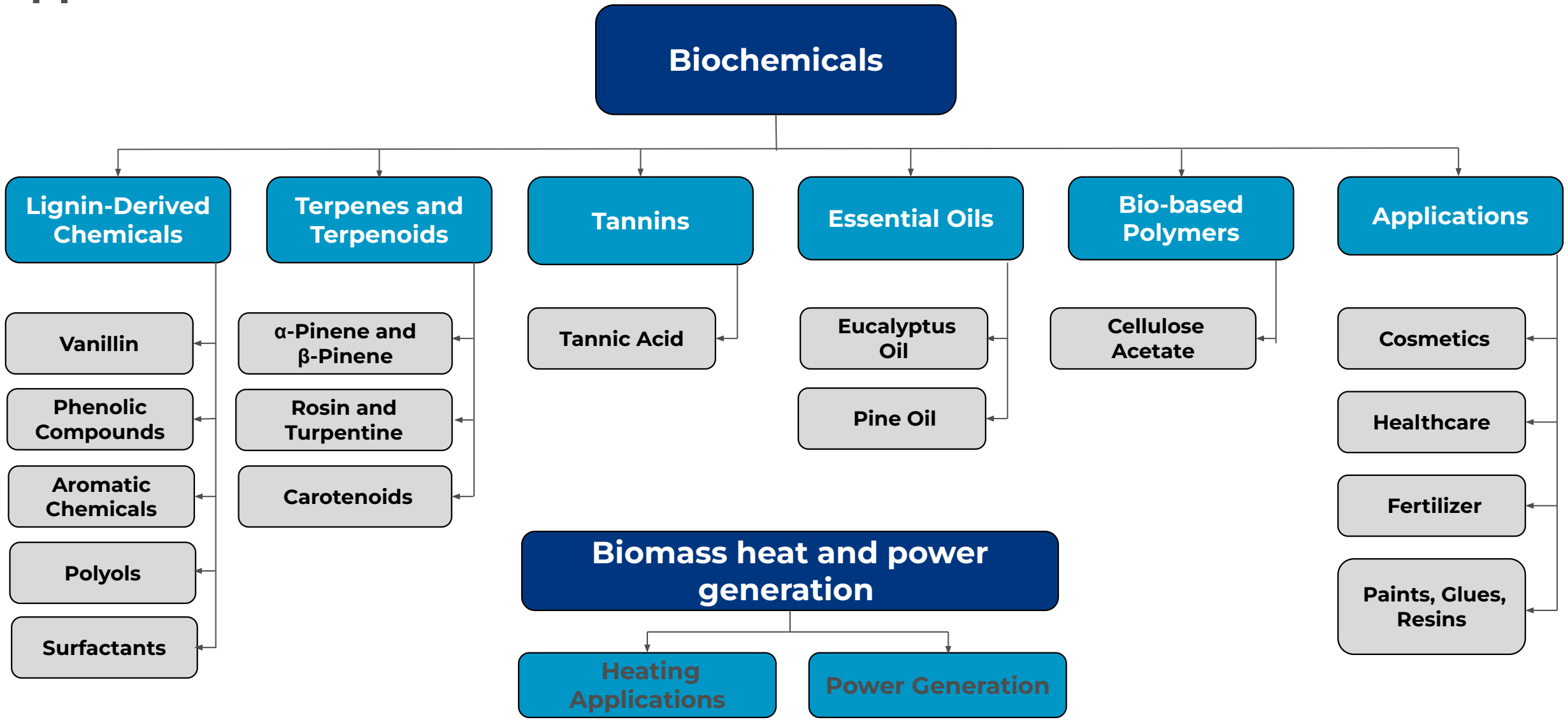
Technology Taxonomy – Module C – 'Value-Added Products/ Materials/ Applications'



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PATENT INSIGHTS
Executive Summary

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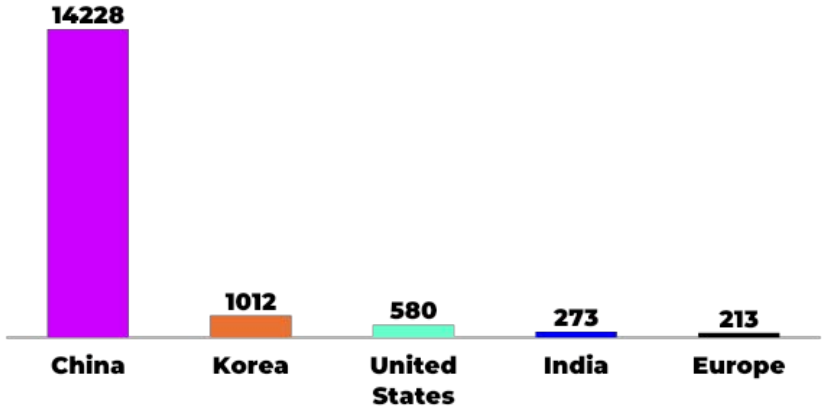
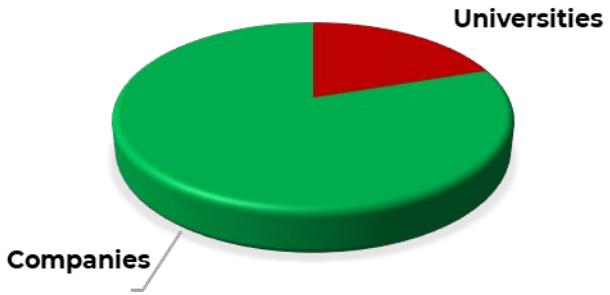
Patent Insights - Executive Summary

Key Jurisdictions

- China dominates the space with ~85% of the total patent assets.
- China is followed by Korea and the U.S.
- Canada stands at the 9th position with ~150 patent assets.



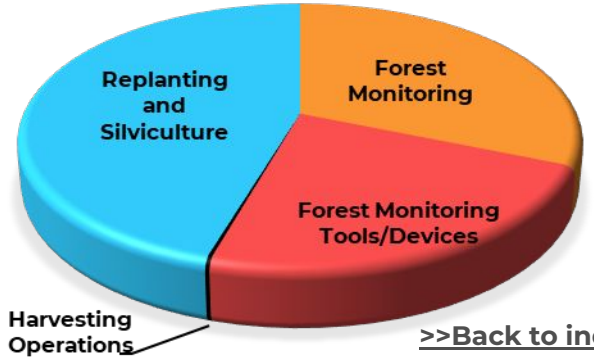


Key Assignees

- As China holds the maximum patent portfolio, Chinese players dominate this technology area with ~80% share.
- ~25% (~5k) of the patent assets have been filed by universities or institutes globally. Among them, the Chinese universities have the major share (80%), followed by the Korean and the Russian universities.

Key Categories

- Replanting & Silviculture category has the largest share (45%) followed by Forest monitoring, and Forest monitoring tools/devices. Harvesting operations category has the lowest share (~1%) (this category covers concepts related to site selection, selective logging, etc. for harvesting).



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Filing and Geography Trends

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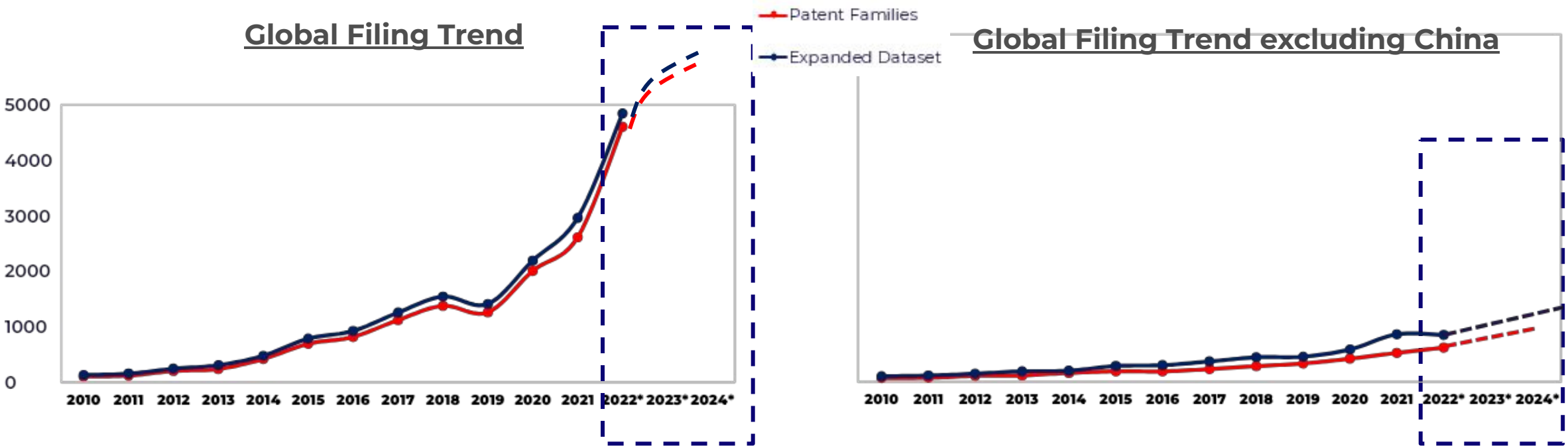
Overall Filing Trend



- The above graphs show comparison between global filing trend and global filing trend excluding China as China holds ~85% of the total patent assets.
- Including China, the total number of active patent families is ~19.5k, and total active patent assets is ~21k. Excluding China, the number of filings per year has reduced by ~80% in the recent years.
- More than 90% of the total patent assets have remaining life above 5 years.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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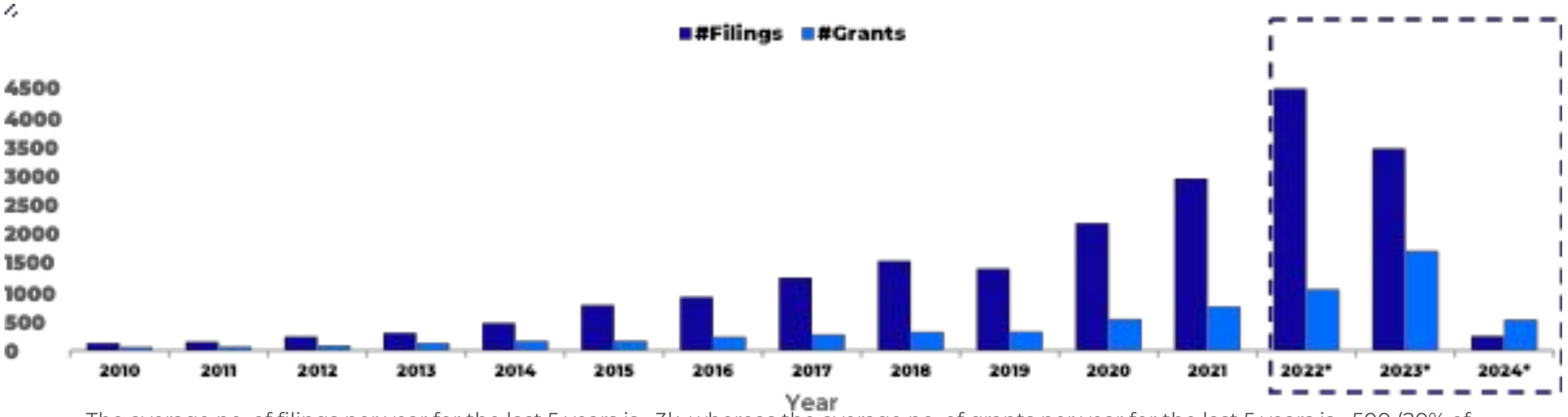
Filing Trend vs. Grant Trend



- The average no. of filings per year for the last 5 years is ~3k, whereas the average no. of grants per year for the last 5 years is ~500 (20% of average filings per year).
- Canada has ~108 pending applications and ~44 granted patents in this domain.
- Companies with highest number of grants are CHINESE ACADEMY OF SCIENCE (147) > INST CHEM IND FOREST PROD CHINESE ACAD (IFPEN) (96) > UNIV NANJING FORESTRY (95) > UNIV BEIJING FORESTRY (83), whereas companies with highest filings are STATE GRID CORP OF CHINA (348) > CHINESE ACADEMY OF SCIENCE (257) > UNIV NANJING FORESTRY (213).
- Countries with the highest number of grants are CN (4444) > KR (833) > US (432) > EP (128). Brazil and Russia have around ~60 and ~120 granted patents, respectively.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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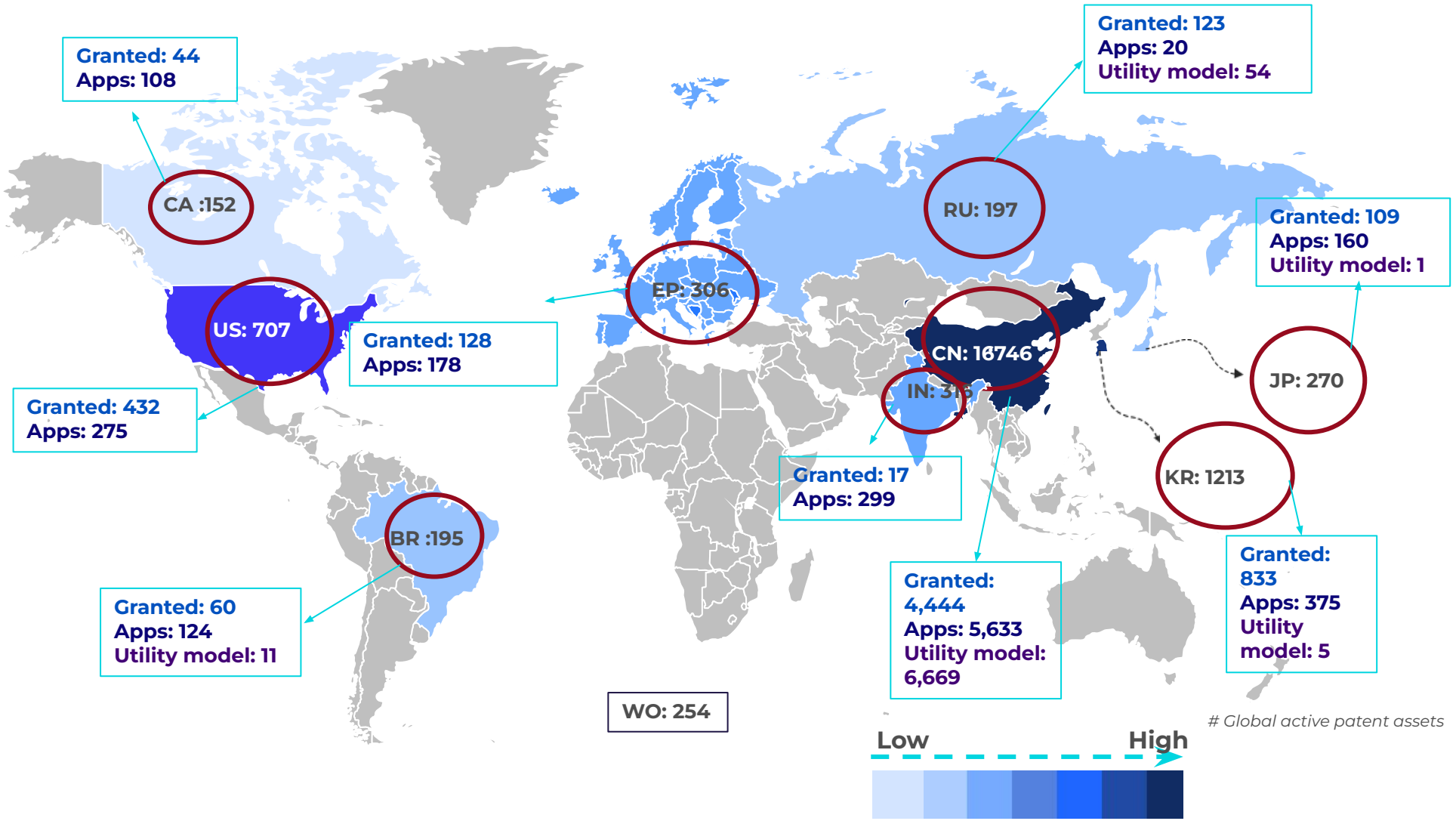
Major Jurisdictions

Top Countries by Patent Distribution	
Country	**Patent #**
China	16,746
Korea	1,213
United States	707
India	316
Europe	306

Top Countries by Forest Area	
Country	**Patent #**
Russia	197
Brazil	195
Canada	152
United States	707
China	16746



 # Global active patent assets

Note: This graph has been prepared using expanded patent dataset.

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Assignee Based Trends

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Key Assignees in Top Countries by Patent Distribution

The below table shows patent distribution among assignees in below countries. The countries are chosen based on the highest patent counts (i.e., top countries having the highest number of patent assets).

CN	KR	US	IN	JP
STATE GRID CORP OF CHINA (348)	KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY (53)	MICROSOFT CORPORATION (22)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (15)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (9)
CHINESE ACADEMY OF SCIENCE (252)	OPUSONE INC (20)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (16)	UNIV LOVELY PROFESSIONAL (10)	BAYER AG (9)
UNIV NANJING FORESTRY (210)	KOREA INSTITUTE OF INDUSTRIAL TECHNOLOGY (20)	BAYER AG (15)	UNIV VIT AP (4)	YAMAHA MOTOR CO. LTD. (8)
INST CHEM IND FOREST PROD CHINESE ACAD (189)	KOREA ADVANCED INSTITUTE FOR SCIENCE AND TECHNOLOGY (19)	BASF SE (12)	UNIV REVA (4)	NIPPON PAPER GROUP INC (8)
UNIV BEIJING FORESTRY (185)	NAT INST FOREST SCI (18)	WEYERHAEUSER CO. (11)	DRYAD NETWORKS GMBH (4)	BOEING CO. (THE) (8)
GUANGXI ZHUANG AUTONOMOUS REGION INST (184)	ELECTRONICS AND TELECOMMUNICATIONS RESEARCH INSTITUTE (14)	BOEING CO. (THE) (11)	BAYER AG (4)	BASF SE (6)
CHINA SOUTHERN POWER GRID CO LTD (141)	SEOUL NATIONAL UNIVERSITY (13)	INTEL CORPORATION (9)	UNIV GRAPHIC ERA (3)	SUNLIT SEEDLINGS LTD (5)
UNIV NORTHEAST FORESTRY (110)	KOREA FORESTRY ADMIN FORESTRY RES (13)	DEERE & CO. (9)	UNIV CHANDIGARH (3)	SHINSHU UNIVERSITY (5)
SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (83)	REPUBLIC KOREA (10)	MIGHTY FIRE BREAKER LLC (8)	SRI ESHWAR COLLEGE ENG (3)	ADEKA CORPORATION (FORMER ASAHI DENKA) (5)
UNIV CENT SOUTH FORESTRY & TECHNOLOGY (69)	GYEINGSANG NATIONAL UNIVERSITY (10)	XIAOMI INC (7)	QUALCOMM INC (3)	SUMITOMO FORESTRY CO LTD (4)
UNIV ZHEJIANG A & F (67)	KYUNGPOOK NATIONAL UNIVERSITY (9)	IFLIGHT INNOVATION TECHNOLOGY LTD (7)	CORTEVA AGRISCIENCE(FORMER DOW AGROSCIENCES LLC) (3)	SICHUAN FORESTRY & GRASSLAND SURVEY (4)
SHANDONG ACAD AGRIC MACHINERY SCI (61)	KOREA ELECTRIC POWER CORP (9)	ALPHABET INC. (7)		DAIKEN KOGYO KK (4)
NAVINFO CO LTD (59)	BAYER AG (9)	KIA MOTORS CORP. (6)		SICHUAN YANGDI SPACE-TIME TECHNOLOGY CO (3)
INST AGRIC RESOURCES & REGIONAL PLANNING (59)	BASF SE (9)	INDIGO AG INC (6)		PRECISION FORESTRY MEASUREMENT LTD (3)
CHINESE ACAD SCI AEROSPACE INFORMATION (55)	KOREA CONSTR TECHNOLOGY INST (8)	HYUNDAI MOTOR CO. (6)		PLANETARY EMISSIONS MANAGEMENT (3)
CHINESE ACAD TROPICAL AGRIC SCI (52)	UNIV PAICHAI IND ACADEMIC COOP FOUND (7)	THINKWARE SYSTEMS CORP (5)		LOCUS IP CO LLC (3)
CAS GEOGRAPHIC SCI & NATURAL RESOURCES (52)	KOREA UNIVERSITY (7)	MINERAL EARTH SCI LLC (5)		
UNIV CHINA ELECTRONIC SCI & TECHNOLOGY (49)		LOCUS SOLUTIONS IPCO LLC (5)		
UNIV SOUTH CHINA AGRIC (47)		HONEYWELL INTERNATIONAL INC. (5)		

Investment Companies
Energy/Power Sector Companies
Forest related/Bioprocessing Companies
Chemical Manufacturing Companies
Tech Companies
Universities/Institutes

The above table shows key assignees who have filed patents in key jurisdictions. e.g., key assignees who have filed in China, Korea, etc.

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Key Assignees in Top Countries by Forest Area

The below table shows patent distribution among assignees in below countries. The countries are chosen based on the highest forest cover regions (i.e., countries having maximum forest areas).

RU	BR	CA	CN	US
UNIV PETROZAVODSK (25)	BASF SE (19)	BAYER AG (9)	STATE GRID CORP OF CHINA (348)	MICROSOFT CORPORATION (22)
INST ATMOSPHERIC OPTICS (7)	BAYER AG (12)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (8)	CHINESE ACADEMY OF SCIENCE (252)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (16)
UNIV VORON TECH (6)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (8)	BOEING CO. (THE) (6)	UNIV NANJING FORESTRY (210)	BAYER AG (15)
FEDERAL STATE BUDGETARY EDUCATIONAL (4)	DEERE & CO. (5)	WEYERHAEUSER CO. (5)	INST CHEM IND FOREST PROD CHINESE ACAD (189)	BASF SE (12)
UNIV SAMARA STATE AGRARIAN (3)	CORTEVA AGRISCIENCE(FORMER DOW AGROSCIENCES LLC) (5)	PONSSE OYJ (4)	UNIV BEIJING FORESTRY (185)	WEYERHAEUSER CO. (11)
UNIV MISIS NAT SCI & TECHNOLOGY (3)	BOEING CO. (THE) (5)	DRYAD NETWORKS GMBH (4)	GUANGXI ZHUANG AUTONOMOUS REGION INST (184)	BOEING CO. (THE) (11)
FEDERAL STATE BUDGETARY INST (3)	DRYAD NETWORKS GMBH (4)	BASF SE (4)	CHINA SOUTHERN POWER GRID CO LTD (141)	INTEL CORPORATION (9)
ALL-RUSSIAN RES INST FORESTRY & FORESTRY (3)	SUMITOMO CHEMICAL CO. LTD. (3)	LOCUS IP CO LLC (3)	UNIV NORTHEAST FORESTRY (110)	DEERE & CO. (9)
UNIV TOMSK POLYTECHNIC (2)	QUALCOMM INC (3)	INVAIO SCI INT GMBH (3)	SINOCHEM HOLDING (FORMERLY SINOCHEM CORP) (83)	MIGHTY FIRE BREAKER LLC (8)
RESHETNEV INFORMATION SATELLITE SYSTEMS (2)	INDIGO AG INC (3)	FIRST RESOURCE MANAGEMENT GROUP INC (3)	UNIV CENT SOUTH FORESTRY & TECHNOLOGY (69)	XIAOMI INC (7)
PONSSE OYJ (2)	BAYER CROPSCIENCE LP (US) (3)	CORTEVA AGRISCIENCE(FORMER DOW AGROSCIENCES LLC) (3)	UNIV ZHEJIANG A & F (67)	IFLIGHT INNOVATION TECHNOLOGY LTD (7)
MOSCOW LOMONOSOV UNIV (2)	WEYERHAEUSER CO. (2)	THALES (2)	SHANDONG ACAD AGRIC MACHINERY SCI (61)	ALPHABET INC. (7)
DEERE & CO. (2)	UNIV ESTADUAL LONDRINA (2)	SUMITOMO CHEMICAL CO. LTD. (2)	NAVINFO CO LTD (59)	KIA MOTORS CORP. (6)
CENTRE NATIONALE D'ETUDES SPATIALES (2)	METISA BIOTECHNOLOGY CO LTD (2)	MDA SYSTEMS LTD (2)	INST AGRIC RESOURCES & REGIONAL PLANNING (59)	INDIGO AG INC (6)
BOEING CO. (THE) (2)	LOCUS IP CO LLC (2)	INDIGO AG INC (2)	CHINESE ACAD SCI AEROSPACE INFORMATION (55)	HYUNDAI MOTOR CO. (6)
	INST FEDERAL EDUCACAO CIENCIA E TECNOLOG (2)	DEERE & CO. (2)	CHINESE ACAD TROPICAL AGRIC SCI (52)	THINKWARE SYSTEMS CORP (5)
	ENI SPA (2)	CENTRE NATIONALE D'ETUDES SPATIALES (2)	CAS GEOGRAPHIC SCI & NATURAL RESOURCES (52)	MINERAL EARTH SCI LLC (5)
		BIOCARBON ENG LTD (2)	UNIV CHINA ELECTRONIC SCI & TECHNOLOGY (49)	LOCUS SOLUTIONS IPCO LLC (5)
			UNIV SOUTH CHINA AGRIC (47)	HONEYWELL INTERNATIONAL INC. (5)

Investment Companies
Energy/Power Sector Companies
Forest related/Bioprocessing Companies
Chemical Manufacturing Companies
Tech Companies
Universities/Institutes

The above table shows key assignees who have filed patents in key jurisdictions. e.g., key assignees who have filed in Russia, Brazil, etc.

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Technology Fragmentations

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New Ventures BC

The below representation describes the distribution of patent assets across taxonomy nodes.

Sustainable Forest Management

Forest Monitoring

- Tree Health/Growth Assessment (1581 | 1493)
- Land Characteristics Assessment (848 | 800)
- Forest Inventory Management (1379 | 1290)
- Wildfire (2279 | 2106)
- Storms (37 | 36)
- Landslides/Earthquakes (110 | 109)
- Hydrological Events (86 | 85)
- Insect/Diseases Outbreaks (70 | 70)
- Real-Time Natural Hazards Monitoring and Management (713 | 692)
- Predicting Natural Hazards (565 | 535)
- Carbon Footprint Tracking (753 | 659)

Forest Monitoring Tools/Devices

- GIS/Satellites (2356 | 2083)
- Drone/UAV (2340 | 2137)
- LiDar (436 | 310)

Forest Replanting and Silviculture

- Reforestation Management (8871 | 8721)
- Tree Growth Enhancement (3904 | 3227)
- Autonomous Replanting/Silviculture (15 | 14)
- AI-enabled Replanting/Silviculture machines (0 | 0)

Harvesting Operations

- Site Selection (3 | 3)
- Selective logging (4 | 4)
- Harvest Residuals Management (25 | 25)
- Direction felling and Sectional Dismantling (4 | 2)
- Harvesting Route Planning (1 | 1)
- Cable Logging Systems (2 | 2)
- Autonomous Harvesting Machines (4 | 1)
- AI-enabled harvesting machines (0 | 0)

Link to Taxonomy Definitions

Note: Numbers in bracket (X | Y) represents (# global active expanded set| # global active patent families)

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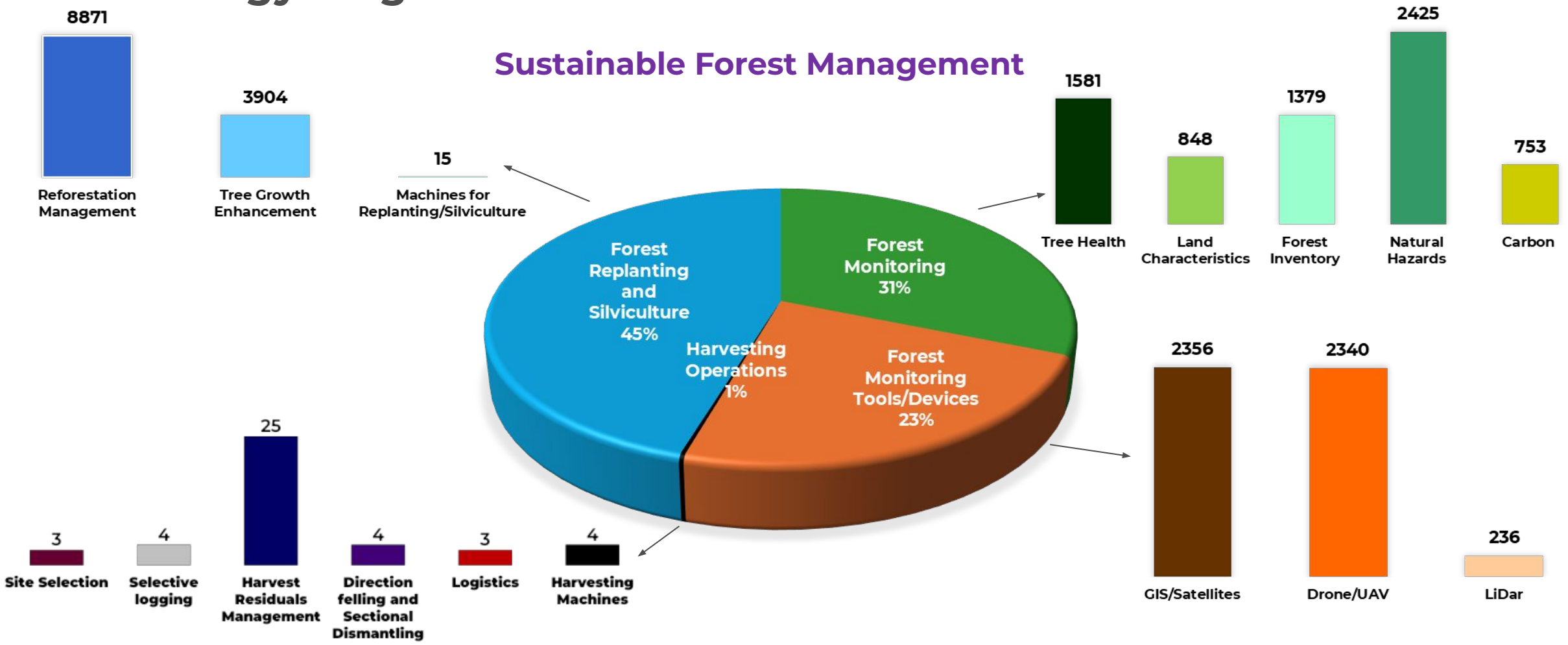
Technology Fragmentations - Global



- The pie chart shows patent distribution among tier-1 categories. Further, the corresponding column graphs show patent distribution in respective tier-2 categories.
- Top countries for most of the tier-1 categories are China, Korea, and the U.S. Brazil and Russia are top countries by forest cover area, but they have fewer filings as compared to these countries.
- Tier-2 categories - Reforestation Management, Natural hazards monitoring, forest monitoring via Satellites and Drones have greater filings as compared to others.

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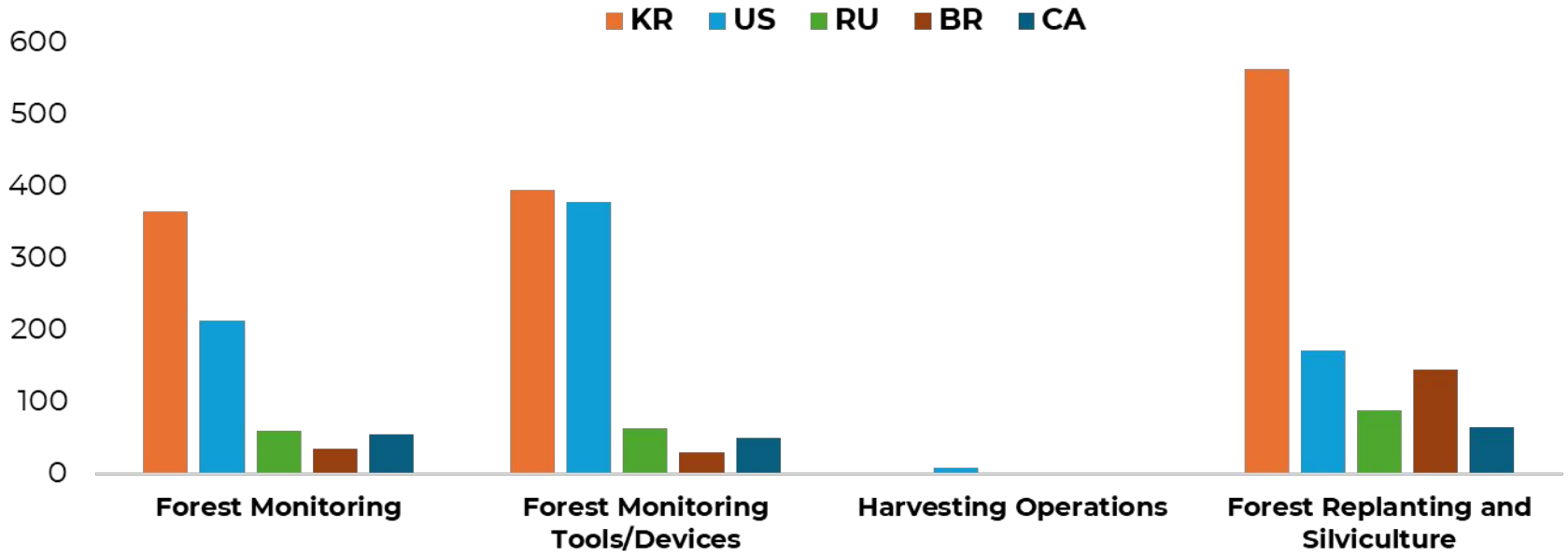
Patent Distribution by Tier-1 Categories in Key Jurisdictions (Excluding China)



Key Assignees			
Forest Monitoring	**Forest Monitoring Tools/Devices**	**Harvesting Operations**	**Forest Replanting And Silviculture**
DRYAD NETWORKS GMBH (54)	BOEING CO. (37)	AIRFORESTRY AB (4)	BAYER AG (117)
BOEING CO. (37)	MICROSOFT CORPORATION (28)	ANDREAS STIHL AG & CODE (2)	SINOCHEM HOLDING (FORMERLY
KOREA INSTITUTE OF SCIENCE AND	DEERE & CO. (25)	SOEDRA SKOGSAEGARNA	SINOCHEM CORP) (101)
TECHNOLOGY (34)	KOREA INSTITUTE OF SCIENCE AND	EKONOMISK FOERENING (1)	BASF SE (85)
LOCUS IP CO LLC (22)	TECHNOLOGY (20)	GNTS LESOPROMYSHLENNOGO	SUMITOMO CHEMICAL CO. LTD. (33)
OPUSONE INC (20)	PONSSE OYJ (19)	KOMPLEKSA STOCK (1)	INVAIO SCI INT GMBH (31)
		BRIDGESTONE CORP.(1)	

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Patent Distribution in Key Countries (Excluding China)

Tier 1 Categories	Tier 2 categories	KR	US	RU	BR	CA
Forest Monitoring	Tree Health/Growth Assessment	77	45	14	12	14
	Land Characteristics Assessment	45	33	6	4	10
	Forest Inventory Management	63	29	17	10	13
	Natural Hazards Tracking	206	76	27	8	17
	Carbon Footprint Tracking	28	52	3	5	13
Forest Monitoring Tools/Devices	GIS/Satellites	136	172	30	15	27
	Drone/UAV	281	166	35	16	15
	LiDar	24	92	14	5	20
Harvesting Operations	Site Selection	-	0	-	-	2
	Selective logging	-	0	-	-	-
	Harvest Residuals Management	-	1	1	1	-
	Direction felling and Sectional Dismantling	-	2	-	-	-
	Logistics	-	2	-	-	-
	Harvesting Machines	-	3	-	-	-
Forest Replanting and Silviculture	Reforestation Management	355	42	71	73	15
	Tree Growth Enhancement	208	130	16	74	50
	Machines for Replanting/Silviculture	-	1	1	-	-

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Canada Based Insights

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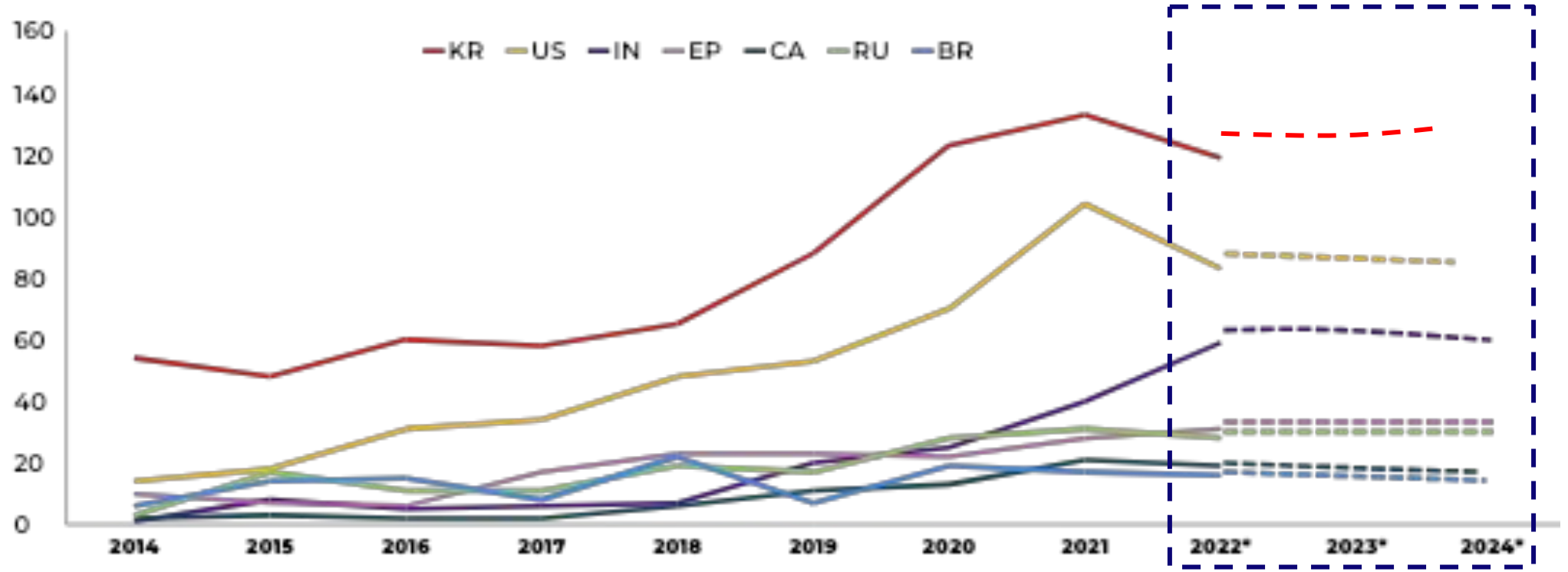
Canadian vs. International Filings – Excluding China



 # Global active patent assets

- The above graph shows patent filling trend in Canada along with other key jurisdictions (excluding China).
- Canada has significantly fewer filings as compared to other key jurisdictions, such as Korea and the U.S. Over the past five years, the average number of filings in Canada has been approximately 11. In contrast, Korea and the U.S. have average filings around 79 and 61, respectively, during the same period.
- The top three countries having maximum forest area are Russia, Brazil and Canada. Russia has greater filings and Brazil has fewer filings as compared to Canada.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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Benchmarking based on Origin Country of Assignees (Key Countries by Patent Distribution)

The below table shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees based in China have filed 14,915 patent families. The countries are chosen based on the highest patent counts (i.e., top countries having the highest number of patent assets).

Global Patent Insights/Country	Chinese Assignees	Korean Assignees	US Assignees	Indian Assignees	Japanese Assignees
Patent Families (INPADOC)	14, 915	959	374	227	111
Expanded Dataset (Total patent applications)	14,825	1,018	770	225	184
Total Granted Patents	3,922	561	369	8	92
Total Pending Applications	4,754	362	398	205	92
Utility Models	6,239	5	-	14	-
Key Assignees	Chinese Academy Of Science, Univ Nanjing Forestry, Inst Chem Ind Forest Prod Chinese Acad	Korea Institute Of Science And Technology, Opusone Inc, Nat Inst Forest Sci	Boeing Co., Monsanto Co., Deere & Co.	Univ Lovely Professional Univ Reva, Sri Eshwar College Eng, Univ Chandigarh	Sumitomo Chemical Co. Ltd., Adeka Corporation, Sony Group, Nippon Soda Co. Ltd.
Key Jurisdictions	CN, KR, US, WO	KR, JP, WO, US	US, EP, CA, BR	IN, CN, US, BR	JP, US, EP, CN

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Benchmarking based on Origin Country of Assignees (Key Countries by Forest Cover)

The below table shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees in Russia have filed 157 patent families. The countries are chosen based on the highest forest cover regions (i.e., countries having maximum forest areas).

Global Patent Insights/Country	Russian Assignees	Brazil Assignees	Canadian Assignees	US Assignees	Chinese Assignees
Patent Families (INPADOC)	157	62	15	374	14, 915
Expanded Dataset (Total patent applications)	157	57	27	770	14,825
Total Granted Patents	95	12	8	369	3,922
Total Pending Applications	17	44	19	398	4,754
Utility Models	45	6	-	-	6,239
Key Assignees	Univ Petrozavodsk, Univ Voron Tech, Inst Atmospheric Optics	BASF SE, Inst Federal Educacao Ciencia E Tecnology	First Resource Management Group Inc, University Of Toronto, Univ Saint Mary's	Boeing Co., Monsanto Co., Deere & Co.	Chinese Academy Of Science, Univ Nanjing Forestry, Inst Chem Ind Forest Prod Chinese Acad
Key Jurisdictions	RU, AR, US, BY	BR, WO, ID, MX	CA, US, WO, EP	US, EP, CA, BR	CN, KR, US, WO

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Patent Insights – Module B – **'Sustainable Bioprocessing'**

Module C – **'Value-Added Products/Materials/Applications'**

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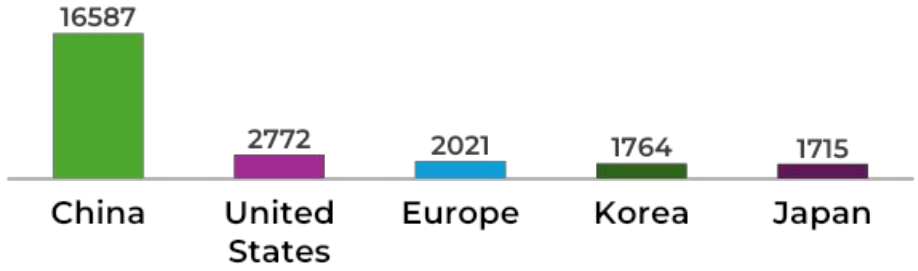
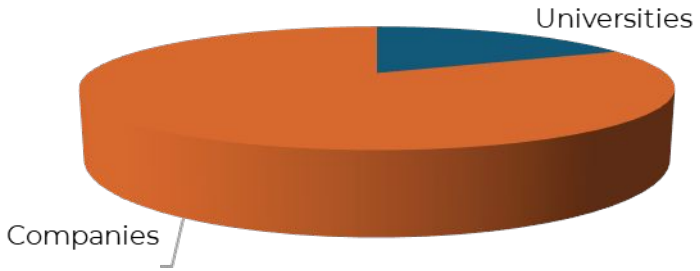
Patent Insights - Executive Summary

Key Jurisdictions

- China owns ~50% of the total patent assets.
- China is followed by the U.S., Europe and Korea.
- Canada stands at the 7th position with ~961 patent assets



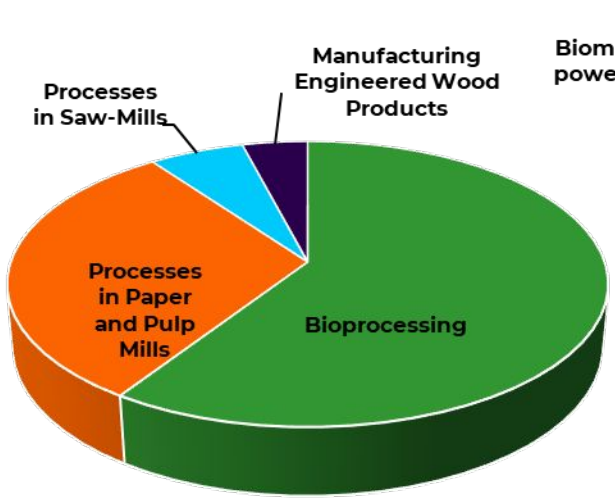


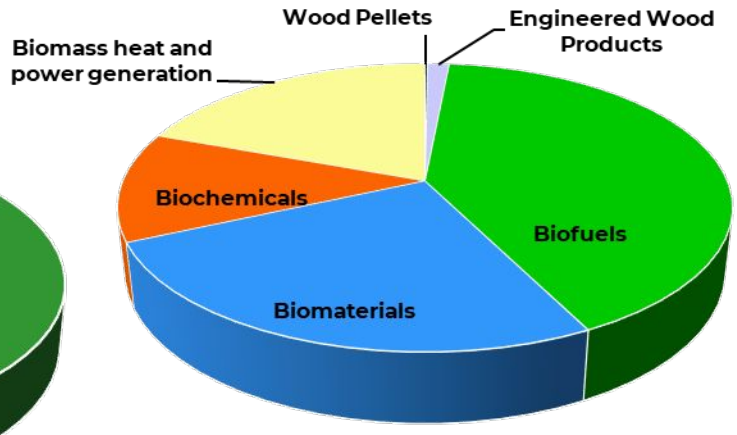
Key Assignees

- As China holds maximum patent portfolio, Chinese players dominate this technology area with ~80% share.
- ~17% (~6k) of the patent set have been filed by universities or institutes globally. Chinese universities have the major share (65%), followed by Korean and US Universities.

Key Categories

- For Sustainable bioprocessing, bioprocessing category has the greatest share (~56%) followed by Processes in Paper and Pulp Mills (~26%). Comparatively fewer filings observed in processes in sawmills and manufacturing engineered wood products (i.e., ~1% of the patent share each).
- For Value-Added Products / Materials / Application, Significant filings in biofuels (~2%), biomaterials, biochemicals (~1%) and biomass heat and power generation (~0.8%) . Very minimal filings were observed in engineered wood products and wood pellets, at levels below 0.01%.





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Filing and Geography Trends

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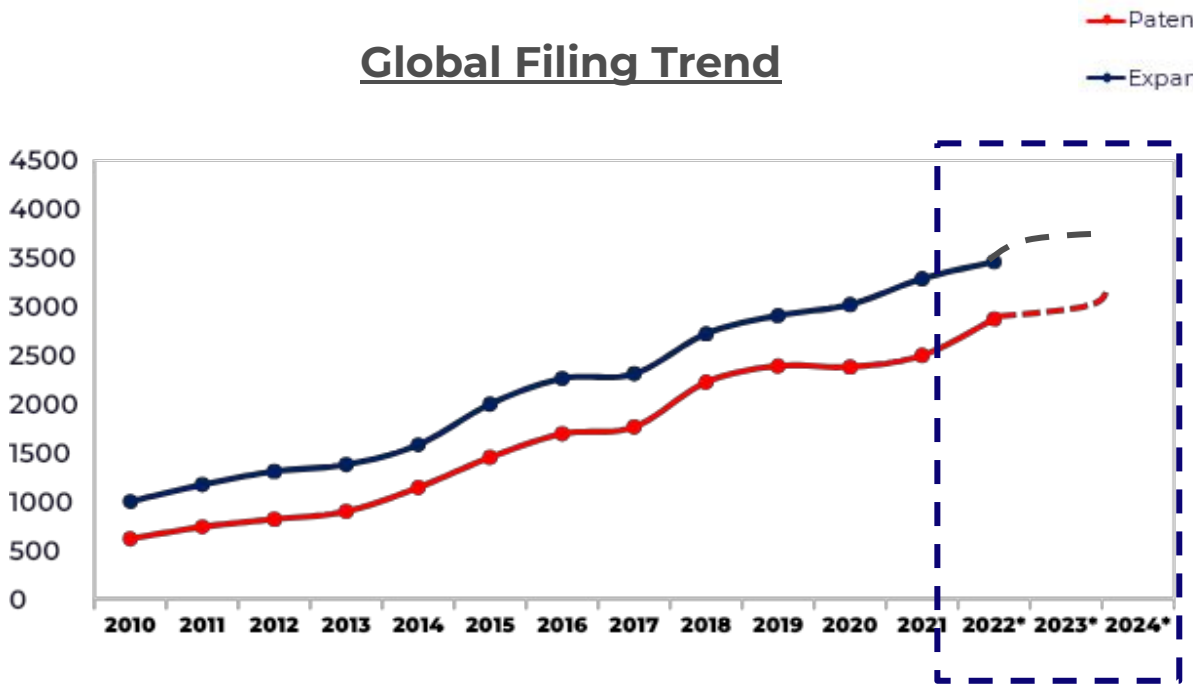
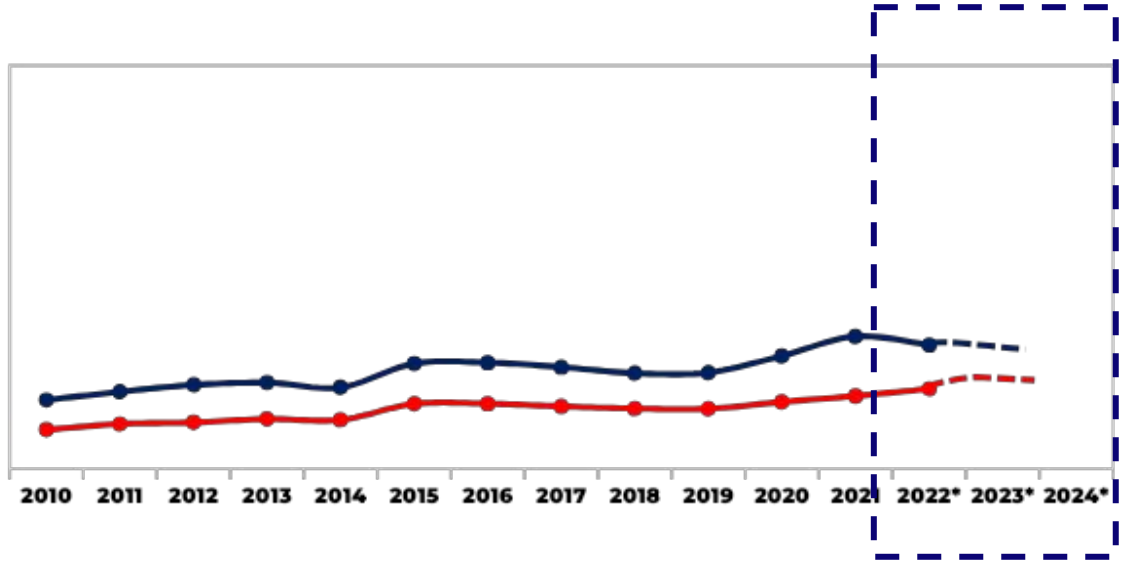
Overall Filing Trend

Global Filing Trend



Global Filing Trend excluding China



- The above graphs show comparison between global filing trend and global filing trend excluding China.
- Including China, the total number of patent families is ~25k, and total active patent assets are ~34k. Excluding China, the number of filings per year has reduced by ~60%.
- More than 90% of the total patent assets have remaining life above 5 years.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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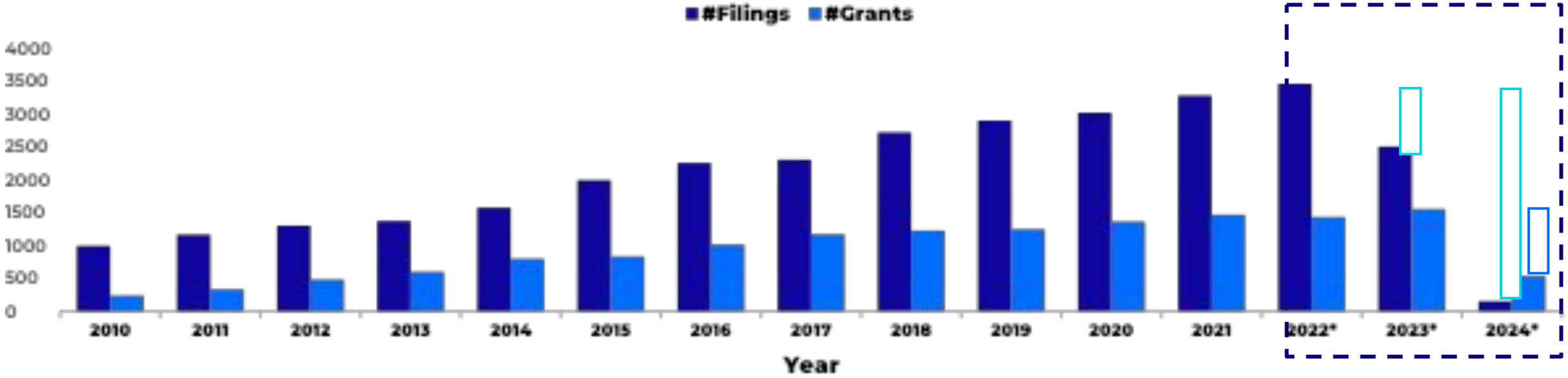
Filing Trend vs. Grant Trend



- The average no. of filings per year for the last 5 years is ~3k, whereas the average no. of grants per year for the last 5 years is ~1,413 (46% of average filings per year).
- Canada has ~475 pending applications and ~486 granted patents in this domain.
- Companies with highest number of grants are CHINESE ACADEMY OF SCIENCE (231) > INSTITUT FRANCAIS DU PETROLE (IFPEN) (192) > WUHAN KAIDI ENG TECHNOLOGY RES INST CO (142) > XYLECO INC (117), whereas companies with highest filings are CHINESE ACADEMY OF SCIENCE (148) > STATE GRID CORP OF CHINA (129) > KEMIRA OYJ (127) > LANZATECH (119)
- Countries with the highest number of grants are CN (5480) > US (1864) > KR (1146) > JP (748). Brazil and Russia have around 300+ granted patents each.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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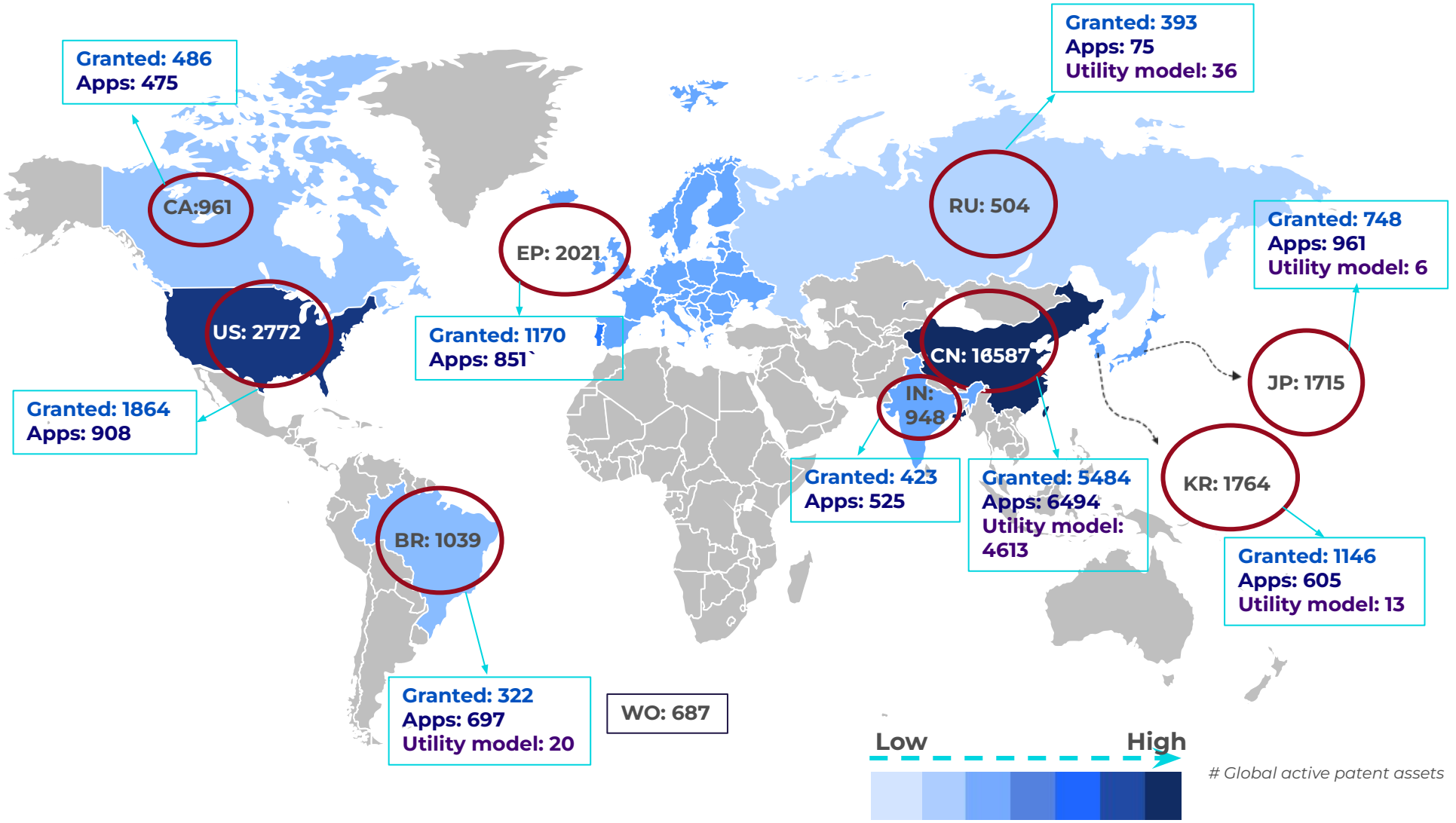
Major Jurisdictions

Top Countries by Patent Distribution	
Country	**Patent #**
China	16,587
United States	2,772
Europe	2,021
Korea	1,764
Japan	1,715

Top Countries by Forest Area	
Country	**Patent #**
Russia	504
Brazil	1,039
Canada	961
United States	2,772
China	16,587



Note: This graph has been prepared using expanded patent dataset.

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Assignee Based Trends

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Key Assignees in Top Countries by Patent Distribution

The below table shows patent distribution among assignees in below countries. The countries are chosen based on the highest patent counts (i.e., top countries having the highest number of patent assets).

CN	US	KR	JP	IN
CHINESE ACADEMY OF SCIENCE (368)	GRANINVESTIMENTOS SA (55)	KOREA INSTITUTE OF ENERGY RESEARCH (KIER) (54)	DAIO PAPER CORP. (55)	COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH (25)
STATE GRID CORP OF CHINA (270)	HONEYWELL INTERNATIONAL INC. (51)	KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY (47)	OJI HOLDINGS CORP (49)	XYLECO INC (20)
CHINA PETROLEUM & CHEMICAL (197)	ANAERGIA INC (40)	KOREA RESEARCH INSTITUTE OF CHEMICAL TECHNOLOGY - SOUTH KOREA (29)	MITSUBISHI HEAVY INDUSTRIES LTD. (47)	INDIAN INSTITUTES OF TECHNOLOGY (20)
SOUTH CHINA UNIVERSITY OF TECHNOLOGY (140)	INSTITUT FRANCAIS DU PETROLE (IFPEN) (38)	KOREA INSTITUTE OF INDUSTRIAL TECHNOLOGY (27)	NIPPON PAPER GROUP INC (37)	LANZATECH (17)
SOUTHEAST UNIVERSITY (95)	EASTMAN CHEMICAL CO (35)	KEMIRA OYJ (21)	DAI NIPPON PRINTING CO. LTD. (33)	WUHAN KAIDI ENG TECHNOLOGY RES INST CO (16)
UNIVERSITY SHANDONG (94)	KEMIRA OYJ (29)	KOREA ADVANCED INSTITUTE FOR SCIENCE AND TECHNOLOGY (20)	TOPPAN HOLDINGS INC (F/K/A TOPPAN INC TOPPAN PRINTING CO. LTD.) (27)	INSTITUT FRANCAIS DU PETROLE (IFPEN) (16)
UNIV KUNMING SCI & TECHNOLOGY (84)	CARBON TECHNOLOGY HOLDINGS LLC (27)	UNIVERSITY OF SEOUL (18)	JFE HOLDINGS INC. (27)	INDIAN OIL CORPORATION LTD (14)
XI'AN JIATONG UNIVERSITY (83)	LANZATECH (26)	INST ADVANCED ENG (18)	ECOLAB INC. (26)	EASTMAN CHEMICAL CO. (12)
INST CHEM IND FOREST PROD CHINESE ACAD (81)	BASF SE (26)	YONSEI UNIVERSITY (17)	MINISTRY OF ECONOMY TRADE AND INDUSTRY (22)	BASF SE (12)
INST AGRIC RESOURCES & REGIONAL PLANNING (78)	VALMET CORPORATION (23)	LANZATECH (17)	KOBE STEEL LTD. (21)	THYSSENKRUPP (10)
CHINA TOBACCO HENAN IND (75)	IOGEN CORP (23)	KOREA RESEARCH INSTITUTE OF STANDARDS AND SCIENCE (17)	CHUGOKU ELECTRIC POWER CO LTD (21)	CLARIANT AG (9)
TONGJI UNIVERSITY (73)	RENMATIX INC (22)	GYEINGSANG NATIONAL UNIVERSITY (17)	LANZATECH (20)	CARBON TECHNOLOGY HOLDINGS LLC (9)
UNIV QILU TECHNOLOGY (132)	ECOLAB INC. (22)	CHONNAM UNIVERSITY (16)	UNICHARM CORP (17)	SHELL PLC (ROYAL DUTCH/SHELL GROUP OF COS) (8)
UNIV NANJING FORESTRY (128)	AIR PRODUCTS AND CHEMICALS INC. (22)	WUHAN KAIDI ENG TECHNOLOGY RES INST CO (15)	NIPPON STEEL CORP (FORMER NIPPON STEEL & SUMITOMO METAL CORP) (16)	HONEYWELL INTERNATIONAL INC. (8)
HUAZHONG UNIVERSITY OF SCIENCE & TECHNOLOGY (125)	NORWOOD IND INC (21)	XYLECO INC (14)	KURITA WATER INDUSTRIES LTD. (16)	ECOLAB INC. (8)
XIAN THERMAL POWER RES INST (105)	XYLECO INC (20)	SEOUL NATIONAL UNIVERSITY (14)	HONDA MOTOR CO. LTD.(HONDA GIKEN KOGYO KK) (16)	TORAY INDUSTRIES INC. (7)
ZHEJIANG UNIVERSITY (72)	BATTELLE MEMORIAL INSTITUTE (20)	ECOLAB INC. (13)	HIROSHIMA UNIVERSITY (15)	INEOS GROUP LIMITED (7)
				DOW CHEMICAL CO. (7)
				RENMATIX INC (6)

Investment Companies
Energy/Power Sector Companies
Forest related/Bioprocessing Companies
Chemical Manufacturing Companies
Tech Companies/Large Scale Manufacturers
Universities/Institutes

Above table shows key assignees that have filed patents in key jurisdictions e.g., key assignees that have filed in China, etc.

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Key Assignees in Top Countries by Forest Area

The below table shows patent distribution among assignees in below countries. The countries are chosen based on the highest forest cover regions (i.e., countries having maximum forest areas).

RU	BR	CA	CN	US
ANDRITZ AG (17)	PETROLEO BRASILEIRO S.A. (22)	NORWOOD IND INC (28)	CHINESE ACADEMY OF SCIENCE (368)	GRANINVESTIMENTOS SA (55)
KEMIRA OYJ (13)	ANDRITZ AG (22)	KEMIRA OYJ (27)	STATE GRID CORP OF CHINA (270)	HONEYWELL INTERNATIONAL INC. (51)
MOSCOW LOMONOSOV UNIV (11)	KEMIRA OYJ (21)	ANAERGIA INC (25)	CHINA PETROLEUM & CHEMICAL (197)	ANAERGIA INC (40)
RENMATIX INC (10)	ECOLAB INC. (21)	LANZATECH (21)	SOUTH CHINA UNIVERSITY OF TECHNOLOGY (140)	INSTITUT FRANCAIS DU PETROLE (IFPEN) (38)
UPM-KYMMENE CORP (9)	VALMET CORPORATION (19)	INSTITUT FRANCAIS DU PETROLE (IFPEN) (19)	SOUTHEAST UNIVERSITY (95)	EASTMAN CHEMICAL CO (35)
SOLENIS LLC (8)	GRANINVESTIMENTOS SA (18)	NESTE OY (FORMERLY NESTE OIL CORP) (13)	UNIVERSITY SHANDONG (94)	KEMIRA OYJ (29)
METSALIITTO OSUUSKUNTA (7)	STORA ENSO AB (17)	ECOLAB INC (13)	UNIV KUNMING SCI & TECHNOLOGY (84)	CARBON TECHNOLOGY HOLDINGS LLC (27)
ECOLAB INC. (7)	BASF SE (17)	VALMET CORPORATION (12)	XI'AN JIATONG UNIVERSITY (83)	LANZATECH (26)
KRONO HOLDING AG (6) CHR. HANSEN HOLDING A/S (6)	INSTITUT FRANCAIS DU PETROLE (IFPEN) (16)	GRANINVESTIMENTOS SA (12)	INST CHEM IND FOREST PROD CHINESE ACAD (81)	BASF SE (26)
BASF SE (6)	CLARIANT AG (14)	FPI INNOVATIONS (12)	INST AGRIC RESOURCES & REGIONAL PLANNING (78)	VALMET CORPORATION (23)
AFYREN (6)	LALLEMAND HUNGARY LIQUIDITY MANAGEMENT (13)	STORA ENSO AB (11)	CHINA TOBACCO HENAN IND (75)	IOGEN CORP (23)
BIOENDEV AB (5)	UPM-KYMMENE CORP (11)	RENMATIX INC (11)	TONGJI UNIVERSITY (73)	RENMATIX INC (22)
MITSUBISHI UBE SIEMENS CORP (4)	INTERNATIONAL FLAVORS & FRAGRANCES INC. (10)	CLARIANT AG (11)	UNIV QILU TECHNOLOGY (132)	ECOLAB INC. (22)
INSTITUT FRANCAIS DU PETROLE (IFPEN) (4)	INST FEDERAL EDUCACAO CIENCIA E TECNOLOGY (10)	CARBON TECHNOLOGY HOLDINGS LLC (11) SOLENIS LLC (10) DANSTAR FERMENT AG (10)	UNIV NANJING FORESTRY (128)	AIR PRODUCTS AND CHEMICALS INC. (22)
ENI SPA (4)	DUPONT DE NEMOURS INC. (10)	BASF SE (10)	HUAZHONG UNIVERSITY OF SCIENCE & TECHNOLOGY (125)	NORWOOD IND INC (21)
	CARBON TECHNOLOGY HOLDINGS LLC (10)	BULAB HOLDINGS INC D/B/A BUCKMAN LABORATORIES INTL (9) UPM-KYMMENE CORP (8)	XIAN THERMAL POWER RES INST (105)	XYLECO INC (20)
			ZHEJIANG UNIVERSITY (72)	BATTELLE MEMORIAL INSTITUTE (20)

Investment Companies
Energy/Power Sector Companies
Forest related/Bioprocessing Companies
Chemical Manufacturing Companies
Tech Companies
Universities/Institutes

Above table shows key assignees that have filed patents in key jurisdictions e.g., key assignees that have filed in China, etc.

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Technology Fragmentations

FORESIGHT

UnitedLex

New Ventures BC

The below representation describes the distribution of patent assets across taxonomy nodes.

Sustainable Bioprocessing

Bioprocessing

Biological Techniques

- Fermentation (4.448 | 3,202)
- Anaerobic and Aerobic Digestion/Composting (1,189 | 912)

Thermo-chemical Techniques

- Pyrolysis and Carbonization (5,810 | 4,730)
- Hydrothermal liquefaction (163 | 106)
- Gasification (4,837 | 3,974)
- Torrefaction (473 | 284)

Biochemical Techniques

- Hydrolysis (1,629 | 1,119)
- Transesterification (357 | 286)
- Supercritical water gasification (14 | 14)

Physical Techniques

- Fractionation (332 | 167)
- Steam-Explosion (181 | 107)
- Pelletizing (74 | 68)
- Briquetting (182 | 149)

Manufacturing Engineered Wood Products

- Hot Pressing (1,143 | 977)
- Cold Pressing (207 | 184)

Processes in Paper and Pulp Mills

Sustainable processes

- Water Conservation (1,640 | 1,200)
- Chemical Recovery and Reuse(128 | 89)
- Energy-Efficient Technologies (758 | 544)
- Treatment of Hazardous Pollutants (558 | 499)
- Waste recycling and Reuse (540 | 466)

Pulp and Paper Processing

- Collection and Sorting (210 | 178)
- Chipping or Grinding (1, 131 | 1,039)
- Mechanical Pulping (1,122 | 744)
- Biochemical Pulping (700 | 603)
- Enzymatic Bleaching (458 | 264)
- Forming Techniques (2,953 | 2,385)

Processes in Saw-Mills

Sustainable processes

- Portable saw-milling (242 | 108)
- Advanced Sawing Equipment (303 | 239)
- Waste Management Techniques (44 | 28)
- Emission Control Technologies (25 | 14)
- Integration with Renewable Energy Systems (75 | 52)

Saw-Mills Processing Techniques

- Sorting and Scaling (358 | 252)
- Debarking (51 | 46)
- Bucking (433 | 319)
- Headrig Sawing (19 | 18)
- Edging and Trimming (215 | 162)
- Planing, Moulding and Profiling (118 | 80)
- Drying (84 | 51)

Note: Numbers in bracket (X | Y) represents (# global active expanded set | # global active patent families)

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The below representation describes the distribution of patent assets across taxonomy nodes.

Value-Added Products/Materials/Applications

Engineered Wood Products

- Particleboard (41 | 39)
- Oriented Strand Board (OSB) (30 | 21)
- Glulam (Glued Laminated Timber) (1 | 1)
- Thermal Modified Timber (0 | 0)
- Laminated Veneer Lumber (LVL) (6 | 6)
- Medium Density Fiberboard (MDF) (25 | 19)
- Plywood (75 | 63)
- Wood fiber-glass (0 | 0)
- Cross-Laminated Timber (CLT) (5 | 2)

Biofuels

Liquid Fuel

- Ethanol (387 | 264)
- Biodiesel (434 | 335)
- Bio oil (352 | 278)
- Biocrude (55 | 37)
- Bio gasoline (5 | 5)
- Bio ethers (0 | 0)
- Aviation biofuel (6 | 6)

Gaseous Fuel

- Biogas (1,154 | 889)
- Syngas (2,059| 1,439)

Solid Fuel

- Biochar and solid carbon (753 | 634)
- Wood-Based Biofuels (268 | 206)

Biomaterials

Wood-Based Biomaterials

- Wood Fiber (49 | 43)
- Lignin (781 | 533)
- Cellulose (1,203 | 799)

Natural Polymers

- Lignin-Based Polymers (40 | 30)
- Chitosan from Fungi (42 | 42)

Mushroom-Based

- Mycelium Composites (38 | 31)

Forest Residue-Based

- Lignocellulosic Biomass (438 | 266)
- Biochar (52 | 37)

Extracts and Essential Oils

- Terpenes (153 | 79)
- Tannins (47 | 40)

Applications

- Aviation and Automotive Parts (22 | 17)
- Textiles (401 | 249)
- Packaging (120 | 84)
- Consumer Goods (54 | 36)

Wood Pellets

- Torrified Pellets (17 | 15)
- Steam Explosion Pellets (4 | 2)

Biomass heat and power generation

- Heating Applications (780 | 673)
- Power Generation (1,818 | 1,673)

Note: Numbers in bracket (X | Y) represents (# global active expanded set| # global active patent families)

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The below representation describes the distribution of patent assets across taxonomy nodes.

Value-Added Products/Materials/Applications

Biochemicals

Lignin-Derived Chemicals

- Vanillin(44 | 32)
- Phenolic Compounds (456 | 335)
- Aromatic Chemicals (128 | 91)
- Polyols (347| 158)
- Surfactants (59 | 42)

Tannins

- Tannic Acid (10 | 10)

Bio based Polymers

- Cellulose Acetate(22 | 17)

Terpenes and Terpenoids

- α-Pinene and β-Pinene (1 | 1)
- Rosin and Turpentine (12 | 9)
- Carotenoids (4 | 4)

Essential Oils

- Eucalyptus Oil (8 | 8)
- Pine Oil (1 | 1)

Applications

- Cosmetics (36 | 34)
- Healthcare (41 | 21)
- Fertilizer (16 | 16)
- Paints, Glues, Resins(462 | 277)

Note: Numbers in bracket (X | Y) represents (# global active expanded set| # global active patent families)

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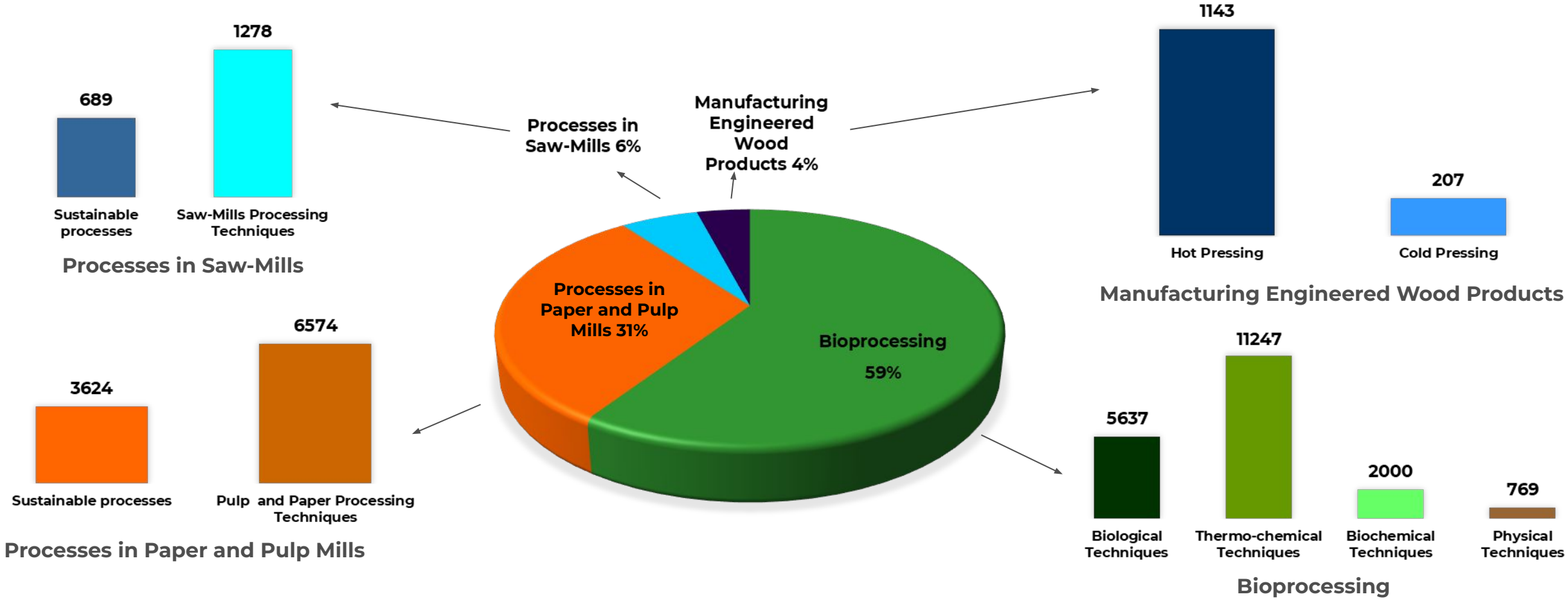
Technology Fragmentations - Global - Sustainable Bioprocessing



- The pie chart shows patent distribution among tier-1 categories. Further, the corresponding column graphs show patent distribution in respective tier-2 categories.
- Further, China is leading in all tier-1 categories. Further, apart from China, top countries for most of the tier-1 categories are US, EP, KR and JP.
- Tier-2 categories – Biological techniques and thermochemical techniques in bioprocessing have greater filings as compared to others.

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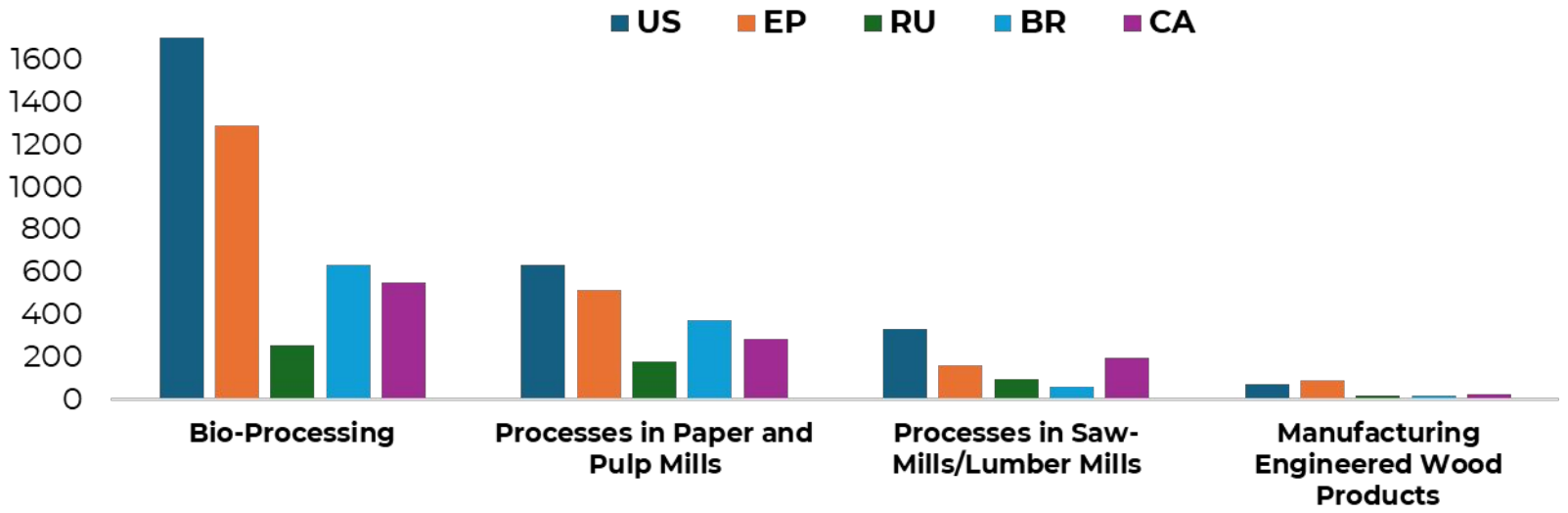
Patent Distribution by Categories for Sustainable Bioprocessing in Key Jurisdictions (Excluding China)



Key Assignees			
Bioprocessing	**PROCESS IN PAPER AND PULP MILLS**	**PROCESSES IN SAW-MILLS**	**MANUFACTURING ENGINEERED WOOD PRODUCTS**
XYLECO (148) INSTITUT FRANCAIS DU PETROLE (121) CHR. HANSEN HOLDING (85) AFYREN (79) LANZATECH (66)	KEMIRA OYJ (94) UPM-KYMMENE CORP (56) DOW CHEMICAL (45) ECOLAB (41) ANDRITZ AG (35)	NORWOOD IND (75) WOODLAND MILLS (16) CALMWAVE (16) PILOT PASTORAL (11) DISCOVERY ENERGY (11)	KRONO HOLDING AG (30) BASF SE (29) KNAUF GIPS KG (17) PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD (9) VALINGE INVEST AB (9)

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Patent Distribution by Tier-2 Categories for Sustainable Bioprocessing in Key Jurisdictions (Excluding China)

Tier 1 Taxonomy Node	Tier 2 Taxonomy Node	US	EP	RU	BR	CA
Bioprocessing	Biological Techniques	600	486	59	258	168
	Thermo-chemical Techniques	902	583	147	203	277
	Biochemical Techniques	198	151	33	139	68
	Physical Techniques	124	69	16	37	36
Processes in Paper and Pulp Mills	Sustainable processes	256	189	69	127	106
	Pulp and Paper Processing Techniques	378	329	112	246	176
Processes in Saw-Mills	Sustainable processes	144	56	20	32	65
	Saw-Mills Processing Techniques	187	102	76	26	130
Manufacturing Engineered Wood Products	Hot Pressing	60	76	15	16	23
	Cold Pressing	13	11	1	4	4

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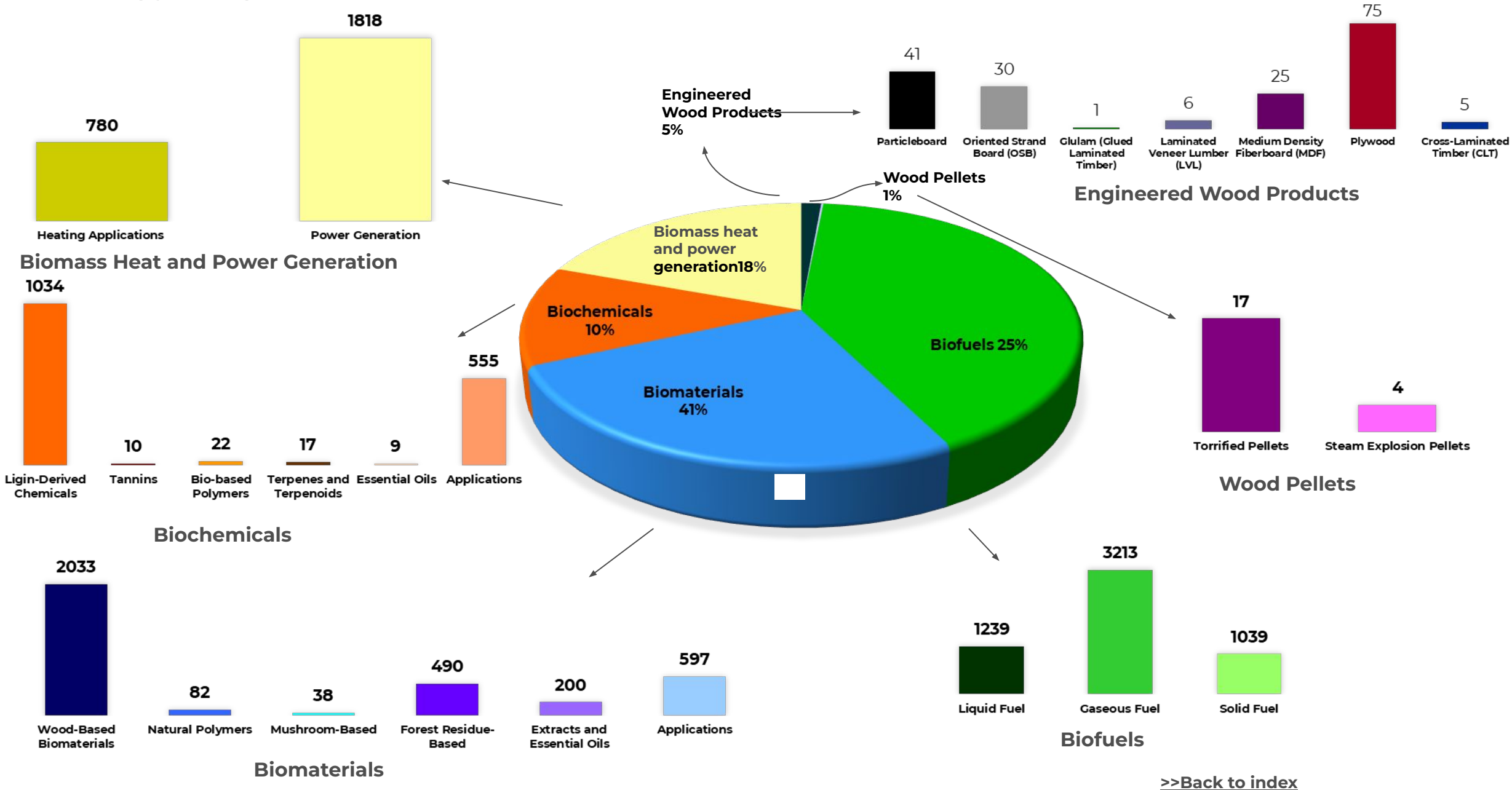
Technology Fragmentations - Global - Value-Added Products / Materials / Application



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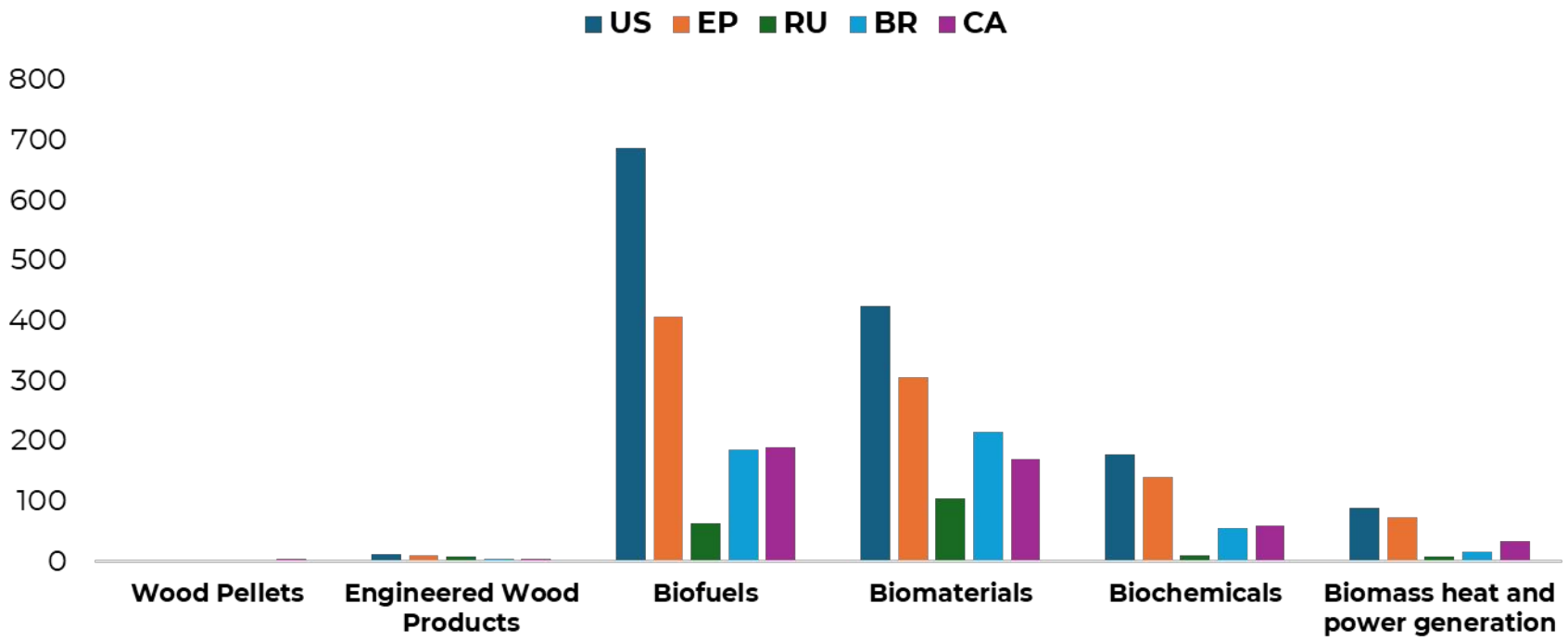
Patent Distribution by Categories for Value-Added Products/Materials/Applications in Key Jurisdictions (Excluding China)



Key Assignees					
WOOD PELLETS	ENGINEERED WOOD PRODUCTS	BIOFUELS	BIOMATERIALS	BIOCHEMICALS	BIOMASS HEAT AND POWER GENERATION
TORREFUSION TECHNOLOGIES (5) NORTH CAROLINA STATE UNIVERSITY (3) RWE AG (2) TORRGAS TECHNOLOGY (2) BIOCARBON IND SARL (1)	KNAUF GIPS KG (3) RENMATIX INC (3) JUNGBYEONGJAE (2) UNIV GADJAH MADA DIREKTORAT PENELITIAN (1) INDIAN PLYWOOD IND RES & TRAINING INST (1)	LANZATECH (57) WUHAN KAIDI ENG TECHNOLOGY RES INST CO (55) INEOS GROUP LIMITED (49) VELOCYS PLC (42) AIR PRODUCTS AND CHEMICALS (30)	STORA ENSO AB (79) GRANINVESTIMENTOS SA (66) FIBERLEAN TECHNOLOGIES LTD (41) RENMATIX INC (41) UPM-KYMMENE CORP (38)	DAI NIPPON PRINTING (33) STORA ENSO AB (32) DIC CORPORATION (24) OWENS CORNING (19) TOPPAN HOLDINGS INC (19)	LANZATECH (41) RIO TINTO PLC (29) MITSUBISHI HEAVY INDUSTRIES (26) E3WATER LLC (20) WUHAN KAIDI ENG TECHNOLOGY RES INST CO (13)

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Patent Distribution by Tier-2 Categories for Value-Added Products/Materials/Applications in Key Jurisdictions (Excluding China): (1/2)

Tier 1	Tier 2	US	EP	RU	BR	CA
Wood Pellets	Torrefied Pellets	3	-	-	1	3
	Steam Explosion Pellets	-	-	-	-	1
Engineered Wood Products	Particleboard	4	1	4	-	2
	Oriented Strand Board (OSB)	2	3	3	3	2
	Glulam (Glued Laminated Timber)	-	-	-	-	-
	Thermal Modified Timber	-	-	-	-	-
	Laminated Veneer Lumber (LVL)	-	-	-	-	-
	Medium Density Fiberboard (MDF)	1	-	-	-	-
	Plywood	1	4	-	2	2
	Wood fiber-glass	3	2	2	-	3
	Cross-Laminated Timber (CLT)	1	1	-	-	-
Biofuels	Liquid Fuel	193	88	14	92	43
	Gaseous Fuel	383	279	38	74	114
	Solid Fuel	111	39	11	19	33

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Patent Distribution by Tier-2 Categories for Value-Added Products/Materials/Applications in Key Jurisdictions (Excluding China): (2/2)

Tier 1	Tier 2	US	EP	RU	BR	CA
Biomaterials	Wood-Based Biomaterials	244	159	67	104	93
	Forest Residue-Based Biomaterials	84	42	12	35	26
	Natural Polymers	9	4	-	3	3
	Extracts and Essential Oils	38	25	2	11	12
	Mushroom-Based Biomaterials	4	2	-	2	1
	Applications	46	74	24	60	35
Biochemicals	Lignin-Derived Chemicals	123	88	8	31	35
	Terpenes and Terpenoids	1	-	1	-	2
	Tannins	-	-	-	-	-
	Essential Oils	-	-	-	-	-
	Bio based Polymers	3	2	-	-	-
	Applications	50	50	2	24	22
Biomass heat and power generation	Heating Applications	47	33	5	9	19
	Power Generation	43	41	3	8	15

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Canada Based Insights

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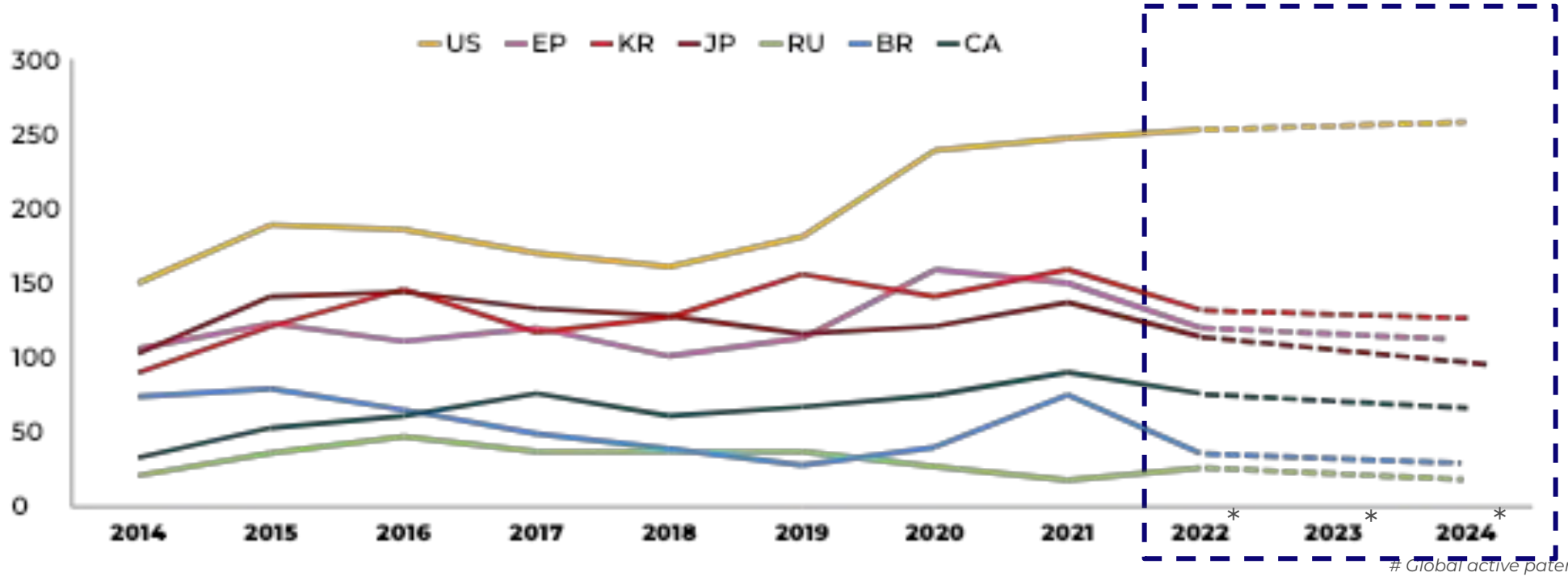
Canadian vs. International Filings (excluding China)



 # Global active patent assets

- The above graph shows patent filling trend in Canada along with other key jurisdictions (excluding China).
- Canada has significantly fewer filings as compared to other key jurisdictions, such as the U.S. and Europe. The average number of filings in Canada has been ~75. In contrast, the U.S. and the Europe have seen average filings around 216 and 130, respectively, during the same period.
- The top three countries having maximum forest area are Russia, Brazil and Canada. Canada has greater filings than Russia and Brazil. Over the past five years, these regions have averaged about 30 and 44 filings respectively, which is significantly lower than Canada's average of ~75 filings.

*Note: * projected numbers have been shown for years 2022-2024 as number may increase as some of the applications filed during this period may not have been published yet.*

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Benchmarking based on Origin Country of Assignees (Key Countries by Patent Distribution)

The graph shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees in China have filed 15,289 patent families. The countries are chosen based on the highest patent counts (i.e., top jurisdictions).

Global Patent Insights/Country	Chinese Assignees	US Assignees	Korean Assignees	Japanese Assignees	Indian Assignees
Patent Families (INPADOC)	15,289	1,917	1,149	735	309
Expanded Dataset (Total patent applications)	15,923	3,894	1,266	1,044	342
Total Granted Patents	5,144	2,146	850	657	135
Total Pending Applications	6,164	1,744	404	384	206
Utility Models	4,615	4	12	3	1
Key Assignees	Chinese Academy of Science, State Grid Corp of China, China Petroleum & Chemical Corp.	XYLECO INC, EASTMAN CHEMICAL CO., LANZATECH, ECOLAB INC.	University of Seoul Industry Cooperation Foundation, LG Chemical Ltd, Republic Korea Man Rural Dev Admin, Doosan Heavy Ind & Construction Co Ltd	Toray Industries, Japan Blue Energy Co Ltd, Dainippon Ink & Chemicals, Toppan Inc	Indian Oil Corp, Council of Scientific and Industrial Research, Reliance Industries
Key Jurisdictions	CN, US, EP, KR	US, EP, CN, CA	KR, US, CN, EP	JP, CN, US, EP	IN, US, EP, BR

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Benchmarking based on Origin Country of Assignees (Key Countries by Forest Cover)

The graph shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees in Russia have filed 191 patent families. The countries are chosen based on the highest forest cover regions.

Global Patent Insights/Country	Chinese Assignees	US Assignees	Russian Assignees	Brazilian Assignees	Canadian Assignees
Patent Families (INPADOC)	15,289	1,917	191	229	285
Expanded Dataset (Total patent applications)	15,923	3,894	193	284	613
Total Granted Patents	5,144	2,146	156	78	357
Total Pending Applications	6,164	1,744	13	190	255
Utility Models	4,615	4	24	16	1
Key Assignees	Chinese Academy of Science, State Grid Corp of China, China Petroleum & Chemical Corp.	XYLECO INC, EASTMAN CHEMICAL CO., LANZATECH, ECOLAB INC.	Univ Voron Tech, Univ Russian State Oil & Gas, Ground Based Space Infrastructure Facil, Sharapov Evgenij Sergeevich	Petroleo Brasilierio SA Petrobras, Suzano SA, Fibria Cellulose SA, Univ Federal Parana	Anaergia Inc, Norwood Ind Inc, FP Innovations, Iogen Corp
Key Jurisdictions	CN, US, EP, KR	US, EP, CN, CA	RU, EP, KR	BR, US, EP, MX	US, CA, EP, BR

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Patent Litigations

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Patent Litigations

No significant litigations were observed in the studied technical areas. Below are exemplary patent litigations in the related domain:

Plaintiff	Type of Plaintiff	Defendant	Filling Date	Patent Details	Technology	Source	Status
DSM IP ASSETS, B.V. & DSM Bio-based Products & Services, B.V.,	Bioprocessing Company	LALLEMAND SPECIALTIES, INC. & MASCOMA LLC,	May 7, 2018	US8795998B2	Ethanol Production	Source	Closed
Alkermes	Pharmaceutical Company	Teva Pharmaceuticals USA, Inc.	September 2020	US7919499B2	Naltrexone long acting formulations	Source	Closed
Bayer	Health and Medical Company	Baxalta, a division of Takeda Pharmaceutical	March 1, 2021	US9364520B2	Biomedical	Source	Closed

- There have been few litigations in the U.S., however, there have been no significant litigations in Canada.
- The number of litigations do not seem to be that significant as compared to other areas (e.g., cloud computing, telecom, etc.). This may be attributed to fewer patent flings in jurisdictions such as US, EP, etc.
- No significant litigations have been observed by NPEs (Non-practicing entities).

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MARKET INSIGHTS
Key Players, Mergers, Acquisitions and Partnerships

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Market Forecast

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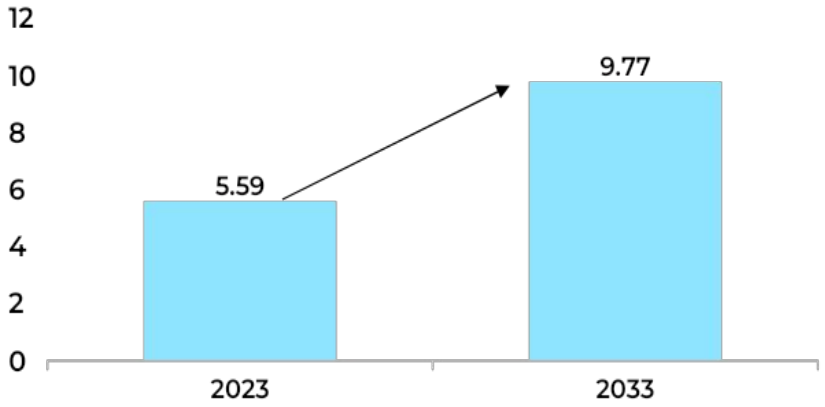
Market Forecast (1/2)

Sustainable Forest Management

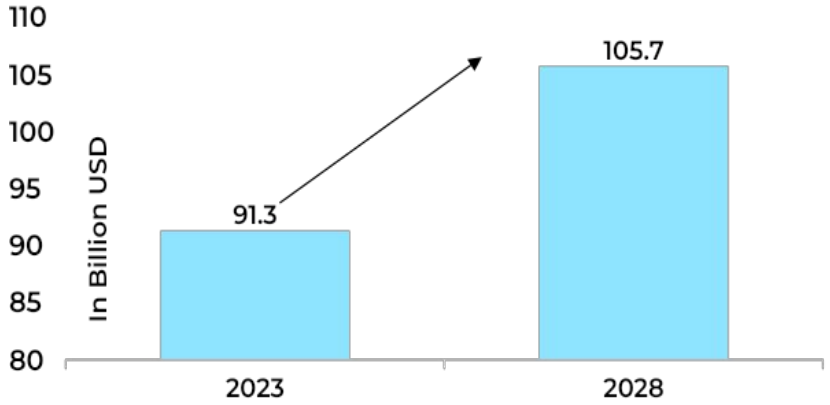
- The global forest management market size was valued at **$5.59 Billion in 2023** and was projected to grow to **$9.77 Billion by 2033** with a **CAGR of 5.74%**.
- North America (the U.S., Canada, Mexico) is anticipated to hold the largest share. Source



Source: Spherical Insights

Sustainable Bioprocessing

- The global biomass power generation market size was valued at **$91.3 Billion in 2023** and was projected to reach **$105.7 Billion by 2028** with a **CAGR of 3.0%**.
- The Asia Pacific region is expected to be the fastest growing region. Source
- The global market for forest bioproducts is estimated to reach **$670 Billion by 2030.** (Source)



Source: Markets and Markets

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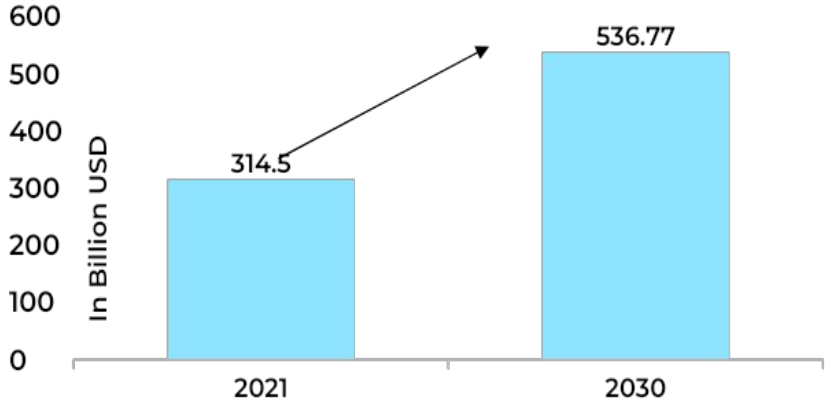
Market Forecast (2/2)

Engineered Wood Products

- The global engineered wood products market was valued at **$314.50 Billion in 2021** and was projected to grow to **$536.77 Billion in 2030** at a **CAGR of 6.12%**.
- North America has the largest share, whereas Asia Pacific region is expected to be the fastest growing region in the engineered wood products market. Source



Source: Skyquest

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Key Players

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TECHNOLOGY TAXONOMY
Module A – 'Sustainable Forest Management'

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Key Players – Sustainable Forest Management (1/3)

The below table shows the list of key players in Sustainable Forest Management:

Companies	Country	Technology focus	Description
Forest Resource Solutions and Technologies	Canada	Forest Management, Forest Monitoring, Forest Inventory Management, Forest Monitoring	FRST Corp provides the full suite of professional forest land management services including forest monitoring, forest inventory analysis, UAV survey, etc. (Source)
Trimble	USA	Forest Management, Forest Harvesting, Forest Logistics, Forest Monitoring	Trimble's Connected Forest solutions deliver integrated software and solutions for collecting, communicating, and analyzing information across and throughout the forestry business, all in real time. (Source)
Komatsu	Japan	Forest Management, Forest Harvesting Management, Forest Monitoring	Komatsu is a leading manufacturer of advanced forest machines and software. Komatsu forest machines are designed to have the least possible impact on the environment while keeping emissions low too.(Source)
Forest Technology Systems	Canada	Forest Monitoring, Natural Hazards Tracking	FTS is a leader in reliable remote automated environmental monitoring solutions for fire, weather and hydrology. (Source)

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Key Players – Sustainable Forest Management (2/3)

Companies	Country	Technology focus	Description
Remsoft	Canada	Forest Management, Forest Monitoring, Forest Harvest Planning	Remsoft forestry software provides intelligent planning & decision optimization analytics for the forestry supply chain and land management. (Source)
Flash Forest	Canada	Forest Management, Forest Monitoring, Forest Replanting and Silviculture	Flash Forest provides advanced technologies such as UAV, AI, GIS, and plant science to scale the reforestation. (Source)
Silvacom FMS	Canada	Forest Management, Harvesting Management, Harvesting Route Planning	Silvacom FMS provides a set of cloud-based geospatial forest management applications and modules, specifically engineered to facilitate the complete forest management process. (Source)
AFRY	Sweden	Forest Management, Forest Monitoring, Forest Inventory Management	AFRY Smart Forestry combines novel software, the latest forestry technology and modern forestry techniques for measuring forests assets. (Source)

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Key Players – Sustainable Forest Management (3/3)

Companies	Country	Technology focus	Description
EOS Data Analytics	USA	Forest Management, Forest Monitoring	EOS Data Analytics provide data analytics solutions for satellite data that can be used in agriculture and forestry sectors. (Source)
Collective Crunch	Finland	Forest Monitoring, Natural Hazards Tracking	Collective Crunch provide forest monitoring solutions that utilise data from optical satellite, synthetic aperture radar (SAR), light detection and ranging (LiDAR). (Source)
Enviva	United States	Forest Management, Forest Monitoring	Enviva Biomass specialize in sustainable forest management and the production of wood pellets as a renewable alternative to coal. (Source)

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KEY PLAYERS
Module B – 'Sustainable Bioprocessing'

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Key Players – Sustainable Bioprocessing (1/8)

The below table shows the list of key players in bioprocessing:

Companies	Country	Technology focus	Description
CMPC	Chile	Pulp and Paper, Biodegradable Fiber, Cellulose	CMPC manufactures pulp and paper products, biodegradable fiber, cellulose, and other bio products by using sustainable processes. (Source)
FITNIR Analyzers	Canada	Advanced and sustainable Pulp and Paper manufacturing equipment and Software for pull mills operations	FITNIR's analyzers reliably measure complete pulp and paper properties, driving process control strategies to optimize pulp mill operations. (Source)
Paper Excellence	Canada	Sustainable Pulp and Paper Manufacturing, Emission Control	Paper Excellence provides pulp and paper products that are certified as 'originating from sustainably managed forests'. The company includes paper and pulp subsidiaries like Resolute Forest Products and Domtar. (Source)
Alberta-Pacific	Canada	Sustainable Pulp and Paper Manufacturing, Energy-Efficient Technologies, Biomethanol	Alberta-Pacific produces natural, renewable and sustainable pulp and paper products. (Source)

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Key Players – Sustainable Bioprocessing (2/8)

Companies	Country	Technology focus	Description
KAM Biotechnology	Canada	Chemical Recovery and Reuse, Treatment of Hazardous Pollutants, Biochemical Pulping, Enzymatic Bleaching	KAM offers biotechnology solutions for the pulp and paper industry that are environmentally safe. It also provides solutions for superior treatment of wastewater. (Source)
Kraft Paper Canada	Canada	Sustainable Pulp and Paper Manufacturing	Kraft Paper Canada produces high-quality paper by implementing environmental policy, sustainable forest management policies for the manufacturing and processing of the pulp and paper products. (Source)
FPInnovations	Canada	Biochemical based pulp and paper production, Engineered wood products	FPInnovations is a not-for-profit R&D private organization to perform state-of-the-art research, develop advanced technologies, and deliver innovative solutions to complex problems for every area of the sector's value chain, from forest operations to consumer and industrial products. (Source)
Asia Pulp & Paper	Indonesia *(Operating in Canada)*	Sustainable Pulp and Paper Manufacturing	APP and its group companies implement sustainable techniques to produce pulp and paper around 150 countries. (Source)

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Key Players – Sustainable Bioprocessing (3/8)

Companies	Country	Technology focus	Description
Canfor	Canada	Sustainable Pulp and Paper Manufacturing, Sustainable Energy Management	Canfor manufactures high quality wood products, and pulp and paper products that offer strength and versatility. Canfor further implements sustainable practices and energy management in pulp and paper manufacturing. (Source)
Ump Paper	Finland	Sustainable Pulp and Paper Manufacturing	Ump Paper implements sustainable manufacturing processes for paper and pulp manufacturing. (Source)
Japan Pulp & Paper	Japan	Sustainable Pulp and Paper Manufacturing	Japan Pulp & Paper manufactures paper and pulp. The company implements sustainability and environmental polices for the processes. (Source)
novozymes	Denmark	Enzymes based pulp and paper production	Novozymes utilizes enzymes for pulp mill, bleach plant and stock preparation for reducing mill's energy footprint and environmental impact. (Source)

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Key Players – Sustainable Bioprocessing (4/8)

Companies	Country	Technology focus	Description
Conifex	Canada	Waste Management Techniques, Lumber Production	Conifex established a 36 MW bioenergy plant for utilizing the biowaste from the saw-mill to produce 230 gigawatt hours (GWh) of energy per year. (Source)
Dunkley Lumber	Canada	Stud and Lumber Products	Dunkley is a participating member in the Western Canada Sustainable Forestry Initiative Implementation Committee (WCSIC) to promote and assist in the implementation of sustainable forest management practices within the purchase wood program. (Source)
Idaho Forest Group	USA	Lumber, Engineered Wood Products	IFG operates saw-mills and uses efficient production processes that use 100% of every tree, ensuring maximum usage of renewable resources. (Source)

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Key Players – Sustainable Bioprocessing (5/8)

Companies	Country	Technology focus	Description
Greenlane Renewables	Canada	Biogas	Greenlane provides biogas systems to biowaste producers to convert their wastes into biogas. (Source)
Anaergia	Canada	Anaerobic Digestion, Biosolids, Biogas, Wastewater Treatment	Anaergia provides biowaste processing such as anaerobic digestion, pyrolysis, *etc.* for producing biosolids and biogas. (Source)
TerraVerdae Bioworks	Canada	Bioplastic	TerraVerdae Bioworks develop sustainable and biodegradable polymers, plastics and products from renewable carbon sources, including waste. (Source)
Canary Biofuels Inc	Canada	Biodiesel	Canary Biofuels comprises multiple biorefineries across Canada for converting biowastes into biofuels. (Source)

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Key Players – Sustainable Bioprocessing (6/8)

Companies	Country	Technology focus	Description
Char Technologies	Canada	Biochar, Syngas, Biocoal	Char Technologies implement high-temperature pyrolysis (HTP) process to convert organic materials (biomass, biosolids, organic waste streams) into biochar, syngas, biocoal, etc. (Source)
Enerkem	Canada	Gasification	Enerkem uses its unique gasification technology to convert waste and biomass residues into sustainable products. (Source)
Anomera	Canada	Cellulose NanoCrystals	Anomera manufactures cellulose nanocrystals from renewable raw materials, sustainably harvested from the forests. (Source)

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Key Players – Sustainable Bioprocessing (7/8)

Companies	Country	Technology focus	Description
CelluForce	Canada	Cellulose NanoCrystals	CelluForce produces nanocrystalline cellulose from wood cellulose. (Source)
Blue Biofuels	USA	Sustainable aviation fuels	Blue Biofuels uses a mechanical-chemical system to convert cellulosic material into biofuels and sustainable aviation fuels by using its novel cellulose-to-sugar (CTS) process. (Source)
EcoSynthetix	Canada	Biopolymers	EcoSynthetix offers a variety of biopolymers that can be used in the manufacturing process for a range of applications in the wood composites, pulp, tissue and paperboard packaging, graphic paper, and personal care. (Source)
Expander Energy	Canada	Gasification	Expander Energy uses its novel gasification technology to convert forest residues in fuels. (Source)

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Key Players – Sustainable Bioprocessing (8/8)

Companies	Country	Technology focus	Description
SBI Bioenergy	Canada	Biofuel	SBI Bioenergy produces green hydrogen from bioethanol for industrial, transportation and residential applications. (Source)
BC Biocarbon	Canada	Pyrolysis	BC Biocarbon uses slow pyrolysis to convert biodegradable biomass into solid, stable, and long-lasting carbon products. (Source)
Origin Materials	Canada	Biochemicals	Origin Materials utilize agricultural wastes and wood wastes for producing biochemicals. (Source)

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TECHNOLOGY TAXONOMY
Module C – 'Value-Added Products/Materials/Applications'

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Key Players – Value-Added Products/Materials/Applications

The below table shows the list of key players in Value-Added Products/Materials/Applications:

Companies	Country	Technology focus	Description
Tolko	Canada	Dimension Lumber, Engineered Wood Products, saw-mills	Tolko manufactures lumber and wood products. (Source)
West Fraser	Canada	Lumber, Medium Density Fiberboard (MDF), Laminated Veneer Lumber (LVL)	West Fraser utilizes biowaste produced from its saw-mills to produce pulp, composite wood products and bioproducts. (Source)
Interfor	Canada	saw-mills, Lumber, Engineered Wood Products	Interfor utilises the byproducts and residuals from its saw-mills to produce energy, heating, and pulp and paper as part of their sustainability initiative. (Source)

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Key Players – Value-Added Products/Materials/Applications

Companies	Country	Technology focus	Description
Weyerhaeuser	USA	Lumber, Engineered Wood Products	Weyerhaeuser manages forests and manufactures wood products. (Source)
Mercer International	USA	Wood Pallets, Wood Pellets, saw-mill, Briquettes	Mercer International produces wood-based products based on sustainable criteria and helps in production of green electricity from biowaste of the wood processing. (Source)

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Key Mergers & Acquisitions

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KEY MERGERS AND ACQUISITIONS
Module A – 'Sustainable Forest Management'

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Mergers and Acquisitions - Sustainable Forest Management (1/3)

The below table shows the mergers and acquisitions between different companies to expand their position in the market:

Primary Entity	Secondary Entity	Year	Details	Source
Trimble (Headquarter – USA)	3LOG Systems (Headquarter – Canada)	2019	3LOG Systems is a software company specializing in the forestry industry. This acquisition complemented Trimble's forestry business software portfolio and further helped to expands the Trimble Connected Forest solutions, which offer a complete end-to-end ecosystem for forest management, traceability and timber processing.	Source
Komatsu (Headquarter – Japan)	Bracke Forest AB (Headquarter – Sweden)	2022	Bracke develops, manufactures, and sells application-specific attachments for use in silviculture processes. Komatsu incorporated Bracke's technologies and expertise in the field of planting in order to accelerate its pace of mechanization of all processes other than harvesting and forwarding.	Source

Mergers and Acquisitions - Sustainable Forest Management (2/3)

Primary Entity	Secondary Entity	Year	Details	Source
Union Park Capital (Headquarter – USA)	Forest Technology Systems (Headquarter – Canada)	2019	FTS deals in environmental monitoring solutions for predicting, preventing, and managing wildfires. It joined Union Park's Advanced Environmental Monitoring Holdings platform ("AE Monitoring").	Source
DJ&A (Headquarter – USA)	Woodland solutions (Headquarter – USA)	2023	DJ&A is a leading environmental, engineering, survey and mapping firm based in Missoula, Montana. This merger brought together WSG's leading geospatial and software capabilities with DJ&A's five decades of engineering, planning, survey, and environmental expertise to create a powerful partnership in the asset management software and geospatial space.	Source

Mergers and Acquisitions - Sustainable Forest Management (3/3)

Primary Entity	Secondary Entity	Year	Details	Source
TÜV SÜD (Headquarter – Germany)	Forest Resource Solutions and Technologies (Headquarter – Canada)	2024	TÜV SÜD acquired Forest Resource Solutions and Technologies to expand its expertise in the validation and verification of climate protection projects. Forest Resource Solutions and Technologies (FRST Corp) provides traditional forestry services related to timberland management and wildfire mitigation and the validation and verification of forest carbon offset projects.	Source

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KEY MERGERS & ACQUISITIONS
Module B – 'Sustainable Bioprocessing'

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Mergers and Acquisitions - Sustainable Bioprocessing (1/5)

The below table shows the mergers and acquisitions between different companies to expand their position in the market:

Primary Entity	Secondary Entity	Year	Details	Source
International Paper (Headquarter –USA)	DS Smith (Headquarter – United Kingdom)	2024	DS Smith deals in packaging solutions in Europe, which complements International Paper's capabilities and might accelerate growth through innovation and sustainability in sustainable packaging solutions.	Source
Mondi (Headquarter – United Kingdom)	Hinton Pulp mill (Headquarter – Canada)	2023	Mondi produces sustainable packaging and paper. It acquired Hinton Pulp mill, which would have helped in forming a fully integrated and much shorter supply chain, reducing the overall carbon footprint of Mondi’s packaging products in the region.	Source
Canfor (Headquarter – Canada)	Millar Western (Headquarter – Canada)	2022	Canfor is an integrated forest products company based in Vancouver. It acquired Milar Western that helped create high-quality, sustainable wood products.	Source

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Mergers and Acquisitions - Sustainable Bioprocessing (2/5)

Primary Entity	Secondary Entity	Year	Details	Source
BTG Group (Headquarter –United Kingdom)	FITNIR Analyzers (Headquarter – Canada)	2023	BTG is a multinational provider of highly specialized process solutions for the global pulp and paper industry, with proven benefits at all levels in the mills. FITNIR specializes in pulp liquor property measurement (on-line and bench top units), which complemented BTG's offerings in Cooking, Bleaching and Chemical Recovery.	Source
Paper Excellence (Headquarter – Canada)	Resolute Forest Products (Headquarter – Canada)	2023	The Paper Excellence Group is a manufacturer of pulp and specialty, printing and writing, and packaging papers. Resolute forest products manufacture products like timber, paper, fruit pulp etc. This collaboration was made to drive sustainable economic activities. This acquisition added adds capabilities in lumber and tissue for Paper Excellence.	Source

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Mergers and Acquisitions - Sustainable Bioprocessing (3/5)

Primary Entity	Secondary Entity	Year	Details	Source
Trafigura (Headquarter – Singapore)	Greenergy (Headquarter- United Kingdom)	2024	Greenergy supplies a range of road fuels including higher percentage biodiesel blends from its rail-fed terminals in Ontario and British Columbia. Earlier, Trafigura Group acquired Greenergy's European operations and now in 2024, it acquired Greenergy's Canadian operations as well.	Source
Greenlane Renewables (Headquarter – Canada)	Airdep S.R.L (Headquarter – Italy)	2022	Greenlane Renewables is a global provider of biogas upgrading systems that helped in decarbonizing of the natural gas. Airdep S.R.L is a provider of biogas desulfurization and air deodorization products based in Vicenza, Italy.	Source

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Mergers and Acquisitions - Sustainable Bioprocessing (4/5)

Primary Entity	Secondary Entity	Year	Details	Source
TerraVerdae Bioworks (Headquarter – Canada)	PolyFerm Canada (Headquarter –Canada)	2022	TerraVerdae, a biopolymers company dedicated to developing sustainable alternatives to petroleum-based plastics, acquired PolyFerm that has a unique technology portfolio of biobased and biodegradable elastomeric polymers known as medium chain length polyhydroxyalkanoate (mcl-PHAs). The addition of PolyFerm helped TerraVerdae to produce biopolymers and resins for a wider range of applications, including for films, coatings and adhesives.	Source
Canary Biofuels Inc (Headquarter – Canada)	Invigor Bioenergy Corporation (Headquarter –Canada)	2021	Canary Biofuels, formed to reduce carbon emissions at scale through sustainable production of biofuels, acquired Invigor Bioenergy Corp, which owns a biodiesel facility in Alberta, to expand its biodiesel facility.	Source

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Mergers and Acquisitions - Sustainable Bioprocessing (5/5)

Primary Entity	Secondary Entity	Year	Details	Source
Biobest (Headquarter- Belgium)	BioWorks (Headquarter- USA)	2023	Biobest acquired BioWorks, Inc. a Victor, NY-based manufacturer of biopesticides. The BioWorks acquisition accelerated Biobest Group's expansion into biopesticides.	Source

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KEY MERGERS & ACQUISITIONS
Module C – 'Value-Added Products / Materials / Applications '

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Mergers and Acquisitions - Value-Added Products/Materials/Applications (1/3)

The below table shows the mergers and acquisitions between different companies to expand their position in the market:

Primary Entity	Secondary Entity	Year	Details	Source
Mercer International (Headquarter – USA)	HIT Holz (Headquarter – Germany)	2023	HIT produces Wood pellets and briquettes, two types of biofuel, from saw-mill residuals. Mercer's solid wood operations in Germany have increased significantly with the help of this acquisition.	Source
Drax Canada (Drax Group Headquarter – UK)	Pinnacle Renewable Energy (Headquarter – Canada)	2021	Drax acquired Pinnacle Renewable Energy Inc. – a major producer and supplier of good quality, compressed bioenergy pellets.	Source

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Mergers and Acquisitions - Value-Added Products/Materials/Applications (2/3)

Primary Entity	Secondary Entity	Year	Details	Source
Star Equity (Headquarter – USA)	Timber Technologies (Headquarter – USA)	2024	Star Equity Holdings, Inc., a diversified holding company, acquired Timber Technologies, LLC, a Wisconsin-based engineered wood products manufacturer.	Source
Resolute (Headquarter – Canada)	Conifex Timber (Headquarter – Canada)	2020	Resolute Forest Products produce a diverse range of wood, pulp, tissue and paper products. Resolute acquired Conifex's three U.S. sawmills. This acquisition helped Resolute to increase its lumber production, specifically, in the U.S. south.	Source
West Fraser (Headquarter – Canada)	Spray Lake saw-mills (Headquarter – Canada)	2023	Spray Lake saw-mills produces treated wood products, dimensional lumber and a variety of innovative wood residuals and biproducts. West Fraser, a diversified wood products company, acquired Spray Lake saw-mills to expand its operating footprints in Alberta.	Source

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Mergers and Acquisitions - Value-Added Products/Materials/Applications (3/3)

Primary Entity	Secondary Entity	Year	Details	Source
Interfor (Headquarter – Canada)	Eacom Timber (Headquarter – Canada)	2021	EACOM owns saw-mills along with an engineered wood plant. The acquisition enabled to increase total lumber production capacity by 25 per cent and helped the company to grow its presence in eastern Canada.	Source
	Chaleur Forest Products (Headquarter – Canada)	2022	Chaleur owns two modern and well-capitalized saw-mill operations located in Belledune and Bathurst, New Brunswick, with a combined annual lumber production capacity of 350 million board feet. This acquisition helped Interfor to increase lumber producer and expand into Eastern Canada.	Source

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Canada Based Startups

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Key Canada Based Startups (1/3)

Company	Industry	Source
4pi Lab	Forest management	Source
Flash Forest	Forest management	Source
NorthPac Forestry Group	Harvesting operations	Source
Tree Track Intelligence	Forest management	Source
Wildfire Innovations	Forest management	Source
Boralife	Value added manufacturing	Source
Arbios Biotech	Biofuel & biogas processing	Source

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Key Canada Based Startups (2/3)

Company	Industry	Source
Benemat Scientific Inc.	Bioprocessing	Source
BryoSphere Biotechnologies	Bioprocessing	Source
Canary Biofuels	Biofuel & biogas processing	Source
Carbon OxyTech Inc.	Bioprocessing	Source
Nfinite Nanotech	Bioprocessing	Source
Ozonebio	Bioprocessing	Source
Sixring Inc	Bioprocessing	Source

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Key Canada Based Startups (3/3)

Company	Industry	Source
Vyterra Renewables	Biofuel & biogas processing	Source
Bioboost Synbio	Biomaterials/bioproducts	Source
BioDiffusion Technologies	Biomaterials/bioproducts	Source
Echo Tech Carbon	Biochar & solid carbon	Source
Terra optima labs	Biochar & solid carbon	Source

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Key Partnerships

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KEY PARTNERSHIPS
Module A – 'Sustainable Forest Management'

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Key Partnerships - Sustainable Forest Management (1/2)

The below table shows the key partnerships between different companies:

Entity 1	Entity 2	Year	Description	Source
Remsoft (Headquarter – Canada)	ForestX (Headquarter – Sweden)	2020	Remsoft entered scandinavian partnership with ForestX to improve forest management and supply chain planning.	Source
Trimble (Headquarter – USA)	Holmen Skog (Headquarter – Sweden)	2024	Holmen Skog, a Swedish forestry company, selected Trimble Connected Forest as its new, comprehensive forest management system to perform data-driven forestry operations in Sweden.	Source
Flash Forest (Headquarter – Canada)	The White Feather Foundation (Headquarter – USA)	2023	The White Feather Foundation joined forces with Flash Forest .to help reforest the site of the devastating Bearhole Lake Fire.	Source
Hummingbird Drones (Headquarter – Canada)	Plymouth Rock Technologies (Headquarter – Canada)	2020	Plymouth Rock Technologies, a threat detection technologies related company, made strategic alliance with Hummingbird Drones for wildfire analysis.	Source

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Key Partnerships - Sustainable Forest Management (2/2)

The table below shows the key partnerships between different companies to expand their position in - Sustainable Forest Management

Entity 1	Entity 2	Year	Description	Source
Wild + Pine (Headquarter – Canada)	Aviva (Headquarter – England)	2023	Aviva PLC partnered with Wild + Pine to restore degraded and marginal land back to a forested landscape, rebuild habitats, and remove carbon dioxide emissions from the atmosphere.	Source
EOS Data Analytics (Headquarter – USA)	Sustainera Solutions (Headquarter – Azerbaijan)	2024	EOS Data Analytics partnered with Sustainera Solutions for the evolution of remote sensing applications for agriculture and forestry.	Source
	Amazon Web Services (AWS) (Headquarter – USA)	2022	EOS Data Analytics partnered with AWS to expands its outreach to large-scale projects promoting sustainable practices for agriculture and forestry markets via satellite imagery analytics.	Source

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KEY PARTNERSHIPS
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Key Partnerships – Sustainable Bioprocessing (1/3)

The below table shows the key partnerships between different companies:

Entity 1	Entity 2	Year	Description	Source
Andion (Headquarter – Canada)	Cogei (Headquarter – Italy)	2021	The companies have established a new consortium company to provide customized anaerobic digestion plants for the waste treatment and renewable energy market.	Source
Anomera (Headquarter – Canada)	Croda (Headquarter – England)	2020	Croda collaborated with Anomera, an award-winning innovator in green chemistry, materials science and sustainable manufacturing, to develop unique and innovative multifunctional ingredients and meet the beauty industry and consumer needs.	Source

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Key Partnerships – Sustainable Bioprocessing (2/3)

Entity 1	Entity 2	Year	Description	Source
Blue Biofuels (Headquarter – USA)	Vertimass (Headquarter – USA)	2024	Blue Biofuels partnered with Vertimass Forge to start production of sustainable aviation fuel.	Source
EcoSynthetix (Headquarter – Canada)	Dow (Headquarter – USA)	2022	Dow partnered with EcoSynthetix to expand bio based offerings to the global personal care market.	Source
Enerkem (Headquarter – Canada)	SHV Energy (Headquarter – Netherlands)	2023	Canada-based Enerkem and SHV Energy initiated feasibility studies for two groundbreaking projects that would convert waste into renewable and recycled carbon DME, a clean-burning fuel that can support decarbonisation of the off-grid energy sector.	Source
Expander Energy (Headquarter – Canada)	IMG Industries (Headquarter – Canada)	2023	Expander and IMG Industries have formed a partnership to manufacture Expander's novel gasifiers under license.	Source

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Key Partnerships – Sustainable Bioprocessing (3/3)

Entity 1	Entity 2	Year	Description	Source
Origin Materials (Headquarter – USA)	Sustainea (Headquarter – Brazil)	2023	Origin Materials and Sustainea partnered to develop 100% bio-based materials. Origin Materials used Origin's technology platform and Sustainea's bio-based glycol products to produce the bio-based materials.	Source
SBI Bioenergy (Headquarter – Canada)	Edmonton International Airport (EIA) (Headquarter – Canada)	2022	Edmonton International Airport (EIA) and SBI Bioenergy worked together to advance the development of sustainable aviation fuel (SAF), biodiesel and hydrogen to lower carbon emissions from on-site activities.	Source
Licella (Australia)	Canfor (Canada)	2020	Arbios Biotech (Arbios), a joint venture of Canadian Forest Products Ltd. (Canfor) and Licella used Licella's pioneering Cat-HTR™ hydrothermal liquefaction (HTL) technology to convert forestry residues and wastes into high value renewable biocrude, which can be further refined to produce low-carbon transportation fuels.	Source

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KEY PARTNERSHIPS
Module C – 'Value-Added Products / Materials / Applications '

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Key Partnerships – Value-Added Products/Materials/Applications (1/2)

The below table shows the key partnerships between different companies:

Entity 1	Entity 2	Year	Description	Source
Pinnacle Renewable Energy (Headquarter – Canada)	Tolko Industries (Headquarter – Canada)	2019	Pinnacle Renewable Energy partnered with Tolko Industries to develop a new industrial wood pellet production facility in High Level, Alberta.	Source
BID Group (Headquarter – Canada)	Canfor (Headquarter – Canada)	2022	BID Group partnered with Canfor to deliver a saw-mill modernization project for its Urbana, Arkansas operation.	Source
Doman (Headquarter – Canada)	Pacific Woodtech (PWT) (Headquarter – USA)	2022	Doman Building Materials Division partnered with Burlington, Washington-based Pacific Woodtech (PWT) to distribute their full line of Engineered Wood Products in Canada.	Source

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Key Partnerships – Value-Added Products/Materials/Applications (2/2)

Entity 1	Entity 2	Year	Description	Source
Gillfor (Headquarter – Canada)	Weyerhaeuser (Headquarter – USA)	2023	Gillfor entered into a strategic partnership with Weyerhaeuser to distribute its line of Truss Joist® Engineered Wood products in the Western Canadian market.	Source

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Key Investments

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KEY INVESTMENTS
Module A – 'Sustainable Forest Management'

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Key Investments – Sustainable Forest Management

Following are few exemplary investments observed in Sustainable Forest Management market:

Companies	Description	Year	Source
Flash Forest (Headquarter – Canada)	Flash Forest raised $11.4M CAD to support reforestation using drones and AI.	2023	Source
FPInnovations (Headquarter – Canada)	FPInnovations received $2M funding for forest truck automation project.	2024	Source
Treeera (Headquarter – Canada)	Treefera raised $12M Series A for AI-platform focused on bringing transparency and accuracy to nature-based asset reporting - such as carbon credits and supply chain sustainability.	2024	Source
Viridis Terra (Headquarter – Canada)	Viridis Terra raised $2.5M USD in seed-stage financing to develop its TreesofLives integrated technology platform to support degraded land restoration.	2021	Source
Trimble (Headquarter – USA)	Trimble Forestry with ForestX invested in the development of Trimble Forestry's Connected Forest product suite to develop a Swedish version of Connected Forest software.	2022	Source

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KEY INVESTMENTS
Module B – 'Sustainable Bioprocessing'

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Key Investments – Sustainable Forest Management

Following are few exemplary investments observed in Sustainable Forest Management market:

Companies	Description	Year	Source
Flash Forest (Headquarter – Canada)	Flash Forest raised $11.4M CAD to support reforestation using drones and AI.	2023	Source
FPInnovations (Headquarter – Canada)	FPInnovations received $2M funding for forest truck automation project.	2024	Source
Treeera (Headquarter – Canada)	Treefera raised $12M Series A for AI-platform focused on bringing transparency and accuracy to nature-based asset reporting - such as carbon credits and supply chain sustainability.	2024	Source
Viridis Terra (Headquarter – Canada)	Viridis Terra raised $2.5M USD in seed-stage financing to develop its TreesofLives integrated technology platform to support degraded land restoration.	2021	Source
Trimble (Headquarter – USA)	Trimble Forestry with ForestX invested in the development of Trimble Forestry's Connected Forest product suite to develop a Swedish version of Connected Forest software.	2022	Source

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Key Investments – Sustainable Bioprocessing (1/3)

Following are few exemplary investments observed in Bioprocessing market:

Companies	Description	Year	Source
Dispersa (Headquarter – Canada)	Dispersa, secured financing of $3M ($1.5M in grants and $1.5M in venture capital), to fund its growth and scale-up of waste-derived biosurfactants that are palm/petroleum-free, non-toxic, and biodegradable.	2023	Source
Enerkem (Headquarter – Canada)	Enerkem closed $255M financing round to drive its growth and deployment of its leading gasification technology.	2022	Source
Airex (Headquarter – Canada)	Airex Energy raised $38M in a funding round that accelerated it's plans to expand its production of low-carbon industrial and agricultural products made from biomass.	2023	Source
Anaergia (Headquarter – Canada)	Anaergia, a Canada-based anaerobic digestion solutions provider, has announced a CAD 40.8M ($30.6M) equity investment by Marny Investissement SA, a Luxembourg-based holding company.	2024	Source
Andion Global (Headquarter – Canada)	Andion Global secured $270M to expand operations and deployment of waste processing plants to upcycle organic waste and create renewable energy.	2022	Source
Paper Excellence (Headquarter – Canada)	Paper Excellence received $4.5M from Catalyst Port Alberni to expand the mill's production capacity for food packaging papers.	2022	Source

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Key Investments – Sustainable Bioprocessing (2/3)

Companies	Description	Year	Source
BC Biocarbon (Headquarter – Canada)	Ministery of Natural Resources of Canada, announced a $10 million contribution to BioLesna Carbon Technologies LP, a joint venture between BC Biocarbon and Dunkley Lumber Ltd., for a new biorefinery in Carrot River, Saskatchewan.	2023	Source
Bioform (Headquarter – Canada)	Suzano Ventures, the corporate venture capital arm of Suzano, has made a strategic investment into the Canadian materials science startup, Bioform Technologies. The investment provides up to US $5 million towards the company's seed round, enabling it to accelerate the development of its novel bio-based plastic alternatives.	2024	Source
BOSK Bioproducts (Headquarter – Canada)	Government of Canada provided $1M in financial assistance to BOSK Bioproducts for improving its capacity to produce compostable bioplastics.	2024	Source
Braya (Headquarter – Canada)	Braya Renewable Fuels received $300M investment from Energy Capital Partners. The company intended to use the funds to support conversion of its refinery operations and accelerate renewable fuels production.	2023	Source

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Key Investments – Sustainable Bioprocessing (3/3)

Companies	Description	Year	Source
Woodland Biofuels (Headquarter – Canada)	The Canadian government invested $4.7 million in Woodland Biofuels, a Toronto-based company that is using gasification and a series of catalytic reactions to convert biomass into renewable fuels.	2019	Source
CHAR Technologies (Headquarter – Canada)	Minister of Energy and Natural Resources Canada, Jonathan Wilkinson, unveils a federal investment of $15 million for six clean fuels projects across Canada, with CHAR Tech among the recipients.	2024	Source
Terragia Biofuel (Headquarter – Canada)	Terragia Biofuel has raised a $6 million seed round to pursue using a “novel” thermophilic bacteria process to break down cellulosic biomass and convert it into ethanol for biofuels such as sustainable aviation fuel.	2024	Source
Enerkem (Headquarter – Canada)	Repsol joined the shareholder base of Enerkem with a €54 million equity investment and an additional €68 million through the subscription of convertible notes. This might help Repsol in becoming zero net emissions by 2050.	2022	Source

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KEY INVESTMENTS
Module C – 'Value-Added Products/Materials/ Applications '

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Key Investments – Value-Added Products/Materials/Applications

Following are few exemplary investments observed in value-added products:

Companies	Description	Year	Source
Tolko (Headquarter – Canada)	Government of British Columbia is investing up to $8M to support engineered wood production in Kamloops, B.C. The investment allows Tolko to build on its existing suite of value-added wood products by leveraging the high-quality and superior technical attributes of B.C.'s timber.	2024	Source
Kalesnikoff (Headquarter – Canada)	Kalesnikoff, a mass timber products and lumber company, announced a new $34 million mass timber mill in B.C.	2024	Source

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Emerging Technologies

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Emerging Technologies	Impact on Market
Internet of Things (IOT)	• Enables to implement the real-time monitoring of the forest environment in terms of tracking fire accidents, monitor the health of the crop, continuous assessment of the vegetation, and real-time tracking of forest logging • Agriculture IOT market (Precision Forestry is one of its application area) is estimated to grow from USD 11.4 billion in 2021 to USD 18.1 billion by 2026 at a CAGR of 9.8%. (Source)
Artificial Intelligence/Machine Learning	• Enables automated analysis of satellite images to detect deforestation, illegal logging activities, etc. • AI enabled bots may make decisions related to harvesting operations, e.g., which tree to fell, where to perform logging activities, etc. • Helps in mapping and monitoring CO2 stock and other ecosystem services • Global Artificial Intelligence in Forestry and Wildlife Market was valued at US $ 1.7 Billion in 2023 and is expected to reach US $ 16.2 Billion by 2032 growing at a CAGR of 28.5% during the forecast period 2024 – 2032. (Source)
Blockchain	• Might replace the current paper (hard copies/physical documents) trail used for tracking with digital records • Provides a secure and transparent method of tracking and verifying the origin and movement of forest products. • The blockchain market size revenue was valued at $12.4 billion in 2023 and is expected to grow at a compound annual growth rate (CAGR) of more than 57% over the forecast period. (Source)
Digital Twin	• Builds decision support systems for operations management. • Implements and monitors forest health treatments and builds predictive models for the early detection of disturbances like forest fire. • The digital twin market size was valued at $17.5 billion in 2023 and is expected to grow at a CAGR of 36.3% over the forecast period. (Source)

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Emerging Technologies	Impact on Market
Consolidated Bioprocessing (CBP)	• CBP consolidates the processes of enzyme production, hydrolysis, and fermentation into a single step, reducing the overall complexity of the biofuel production process. • The consolidation leads to less equipment, lower energy costs, and a decrease in water and chemical inputs associated with each process stage. This helps to make the process more economically-viable and sustainable. • Bioprocess Technology Market (consolidated bioprocessing is also a part of it) was valued at USD 29,356.1 million in 2023 and is expected to grow at 12.7% CAGR from 2024 to 2030. (Source)
Carbon-negative Solutions	• Carbon-negative bioprocessing aims to not only minimize carbon emissions but actively remove carbon dioxide (CO2) from the atmosphere. • This approach is essential for combating climate change and promoting sustainability. • The Global Sustainable Carbon Negative Materials Market is estimated to exhibit a CAGR of 9.81% during the forecast period for 2023-2031. (Source)
Machine Learning in Bioprocessing operations	• Optimization of Bioprocessing Operations: Machine learning models can analyze historical data to identify optimal operating conditions for various bioprocessing steps, such as fermentation, distillation, and purification. • Yield Prediction: AI can analyze large datasets from bioprocessing operations to predict biomass yields based on different input variables like feedstock type, processing conditions, and environmental factors. • The global artificial intelligence market size was valued at USD 150.2 billion in 2023 and is expected to grow at a CAGR of 36.8% from 2023 to 2030. (Source) Further, global bioprocess market is expected to grow at a CAGR of 14. 8% from US 30 billion in 2024 to USD 121 billion in 2034 (Source)
IoT for monitoring bioprocessing systems	• IoT-enabled sensors and devices are deployed throughout bioprocessing systems to continuously monitor critical parameters such as temperature, pH, dissolved oxygen, glucose levels, and cell density. • These sensors provide real-time data, allowing for immediate detection of any deviations from optimal conditions. • The IoT Sensor Market Size was valued at USD 51.6 Billion in 2023. The IoT Sensor industry is projected to grow from USD 53.1 Billion in 2024 to USD 150.3 Billion by 2032, exhibiting a compound annual growth rate (CAGR) of 17.10% during the forecast period (2024 – 2032). (Source)

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Government Policies and Initiatives

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Canadian Government Policies and Initiatives: (1/2)

Canada accounts for only ~0.3% of global deforestation. Canadian government seem to be actively taking initiatives to improve forest management in Canada. Below are few recent policies/initiatives/developments made by the Canadian government to promote Sustainable Forestry.

To uphold the sustainable forest management decisions and activities, **the Government of Canada developed federal, provincial, territorial and municipal forest laws, regulations and policies**. The objective of these measures is to provide guidance and to ensure the implementation of sustainable forest management practices and standards on both public and private lands nationwide. Source

Renewed Forest Bioeconomy Framework - The Renewed Framework, built on the 2017 Forest Bioeconomy Framework for Canada, focuses directly on addressing the continuing challenges the forest sector faces to realize the potential of the forest bioeconomy in Canada. Source

Canadian Bioeconomy Strategy - Canada's Bioeconomy Strategy serves as a call to action for governments and industry to seize the opportunities of an industrial bioeconomy. Canada's competitive advantages for the bioeconomy include: access to biomass, global leadership in forestry and agriculture, sustainable resource management and a skilled workforce. Canada continues to rank first among the Organization for Economic Co-operation and Development (OECD) countries in the proportion of college and university graduates participating in the economy. Source

Forest Carbon Initiative - Province of British Columbia (B.C.) and the federal government are partnering to invest in forest carbon projects across the province. Source

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Canadian Government Policies and Initiatives: (2/2)

- **In Canada, three organizations provide forest management certifications** to ensure that the products produced by the industry are renewable and forestry practices are sustainable :
  - **The Sustainable Forestry Initiative (SFI)**
  - **The Forest Stewardship Council (FSC)**
  - **The Canadian Standards Association (CSA)**

- **Canadian Government Forest Innovation Program –** The program was created in 2012 and was renewed in 2023 to support the first phase of the forest sector innovation process by facilitating R&D for innovative technologies, products, and processes in the emerging bioeconomy. (Source)

- **Ontario Forest Biomass Program –** The program supports the objectives set out in Sustainable Growth: Ontario's Forest Sector Strategy and the provincial Forest Biomass Action Plan (FBAP). The program supports initiatives that secure and increase long-term wood utilization across the province, with a focus on underutilized species and forest biomass. Source

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Global Policies and Initiatives

Below are exemplary policies/initiatives/developments made by the global organizations to promote Sustainable Forestry.

- **In the U.S., National Association of State Foresters implements Federal & Exportation laws** across all 50 states **addressing** the major components of **sustainable forest managemen**t. (Source)
- **The International Tropical Timber Organization (ITTO)** is an intergovernmental organization that **develops internationally agreed policy guidelines and norms to encourage sustainable forest management (SFM) and provides certification for sustainable tropical timber industries and trade.** Major member of ITTO are Brazil, USA, Canada, China. (Source)
- **The Food and Agriculture Organization of the United Nations** helps the United Nation member countries to **overcome the constraints to sustainable forest management by providing information and policy advices**. FAO helps countries define the elements of sustainable forest management in their national contexts and to monitor progress towards it. (Source)
- In Europe, the European Commission monitors that the European forests are subject to national laws and international commitments to ensure their sustainability. (Source)
- Programme for the Endorsement of Forest Certification (PEFC) is an international non-profit, non-governmental organization that provides sustainable forest management through independent third-party certification. (Source)

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Relevant Standards and Standard Essential Patents

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Standard Essential Patent

A Standard Essential Patent (SEP) is a patent granted for technological invention which is essential for implementation and working of a standard. Patents which are essential to a standard and have been adopted by a Standard Setting Organization (SSO) are known as SEPs.

Risks associated with SEPs

- Multiple products/services may infringe on SEPs, if those products/services uses relevant standards (generally, such technology standards are mandatory or important for relevant product/technology, therefore, risk of infringement is high in case relevant SEPs exist in a domain).

- For example, SEPs related to telecom technologies such as 4G, 5G, Wi-Fi, etc., exist globally and are subject to licensing if other companies wants to use those inventions in their products/services. Such SEPs related to telecom technologies may also be applicable in 'Forest Bioeconomy sector' as these technologies are used for communication between various devices (that are used to collect and transmit data or receive and analyze the data).

- Further, relevant standards and role of SEPs in Forest Bioeconomy sector is explained in subsequent slide:

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There seems to be a very few related standards to this domain. Few relevant standards have been provided below:

Standards	Description
CAN/CSA – ISO 17225	Solid Biofuels Standards
SFI standards	Forest Management standards aiming towards a sustainable planet

- Forest bioeconomy encompasses various activities related to the sustainable use of forest resources for economic purposes, including the production of solid biofuels. The CAN/CSA – ISO 17225 standard plays a crucial role in ensuring the quality and reliability of solid biofuels derived from forest biomass.

- Further, a few international standards seem to have related standards specific to preservation of the forest economy such as SFI that contribute to the sustainable management of forests, resulting in increased focus on preserving wildlife habitats, ensuring clean water sources, and expanding the availability of eco-friendly wood, paper, and packaging materials for consumers and businesses.

- No Significant SEPs seem to exist in this domain, therefore, there is no major role of SEPs in Forest Bioeconomy sector.

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British Columbia Based Insights

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	British Columbia	British Columbia	Ontario based	Ontario based Inventors
Patent Families (INPADOC)	4	3	11	7
Expanded Dataset (Total patent applications)	9	8	19	15
Total Granted Patents	1	1	6	4
Total Pending Applications	7	7	13	11
Top Assignees	MDA Systems, Urthecast Corp. and SenseNet Inc	MDA Systems, Urthecast Corp. and SenseNet Inc	First Resource Management Group, University of Toronto and Canada Forests Trust	First Resource Management Group, University of Toronto and Canada Forests Trust
Top Jurisdictions	CA, WO, EP	CA, WO, EP	US, CA, WO	CA, US, WO
Top Categories	Forest Monitoring via Satellites, Wildfire Tracking	Forest Monitoring via Satellites, Wildfire Tracking	Forest Inventory Management, Forest Monitoring via Satellites and LiDar	Land Characteristics, Forest Monitoring via Satellites and LiDar

- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia > Alberta > Ontario > Quebec (also shown in 'VENTURES TO VALUE CHAINS' paper published by Foresight). Ontario based companies seem to have filed more patents than companies in other Canadian provinces. No significant patent filings were observed for Quebec and Alberta based companies/inventors.

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	British Columbia	Ontario based Assignees	Quebec based Assignees	Alberta based Assignees
Patent Families (INPADOC)	4	60	20	15
Expanded Dataset (Total patent applications)	34	80	31	16
Total Granted Patents	17	50	20	10
Total Pending Applications	16	30	11	6
Top Assignees	G4 Insights Inc, Suzano Canada Inc And Canfor Pulp Ltd	Norwood Ind Inc, Iogen Corp And Comet Biorefining Inc	Hydro-quebec, Fpi Innovations and Bulab Holdings Inc	Expander Energy Inc, Air Technic Sro, and Enlighten Innovations Inc
Top Jurisdictions	EP,US,WO	US, EP, WO	US, CA, IN	EP, WO, US
Top Categories	Pyrolysis and Carbonization, Torrefaction and Lignin	Anaerobic and Aerobic Digestion/Composting, Portable Sawmilling, Bucking, and Biogas	Gasification, Syngas and Enzymatic Bleaching	Pyrolysis and Carbonization, Gasification

- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia > Alberta > Ontario > Quebec (also shown in 'VENTURES TO VALUE CHAINS' paper published by Foresight). Ontario based companies seem to have filed more patents than companies in other Canadian provinces.

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	British Columbia based	Quebec based	Ontario based	Alberta based
Patent Families (INPADOC)	31	22	54	17
Expanded Dataset (Total patent applications)	47	31	108	24
Total Granted Patents	25	16	71	12
Total Pending Applications	22	15	37	12
Top Assignees	G4 Insights Inc, Suzano Canada Inc And Performance Biofilaments Inc	Fpi Innovations, Enerkem Inc, Bulab Holdings Inc	Iogen Corp, Norwood Ind Inc and Woodland Mills Inc	Expander Energy Inc, SIXRING INC and Air Technic Sro
Top Jurisdictions	CA, US, EP	CA, WO, EP	US, EP, CA	CA, US, WO
Top Categories	Pyrolysis and Carbonization, Lignin and Cellulose	Gasification, Syngas and Lignin	Anaerobic and Aerobic Digestion/Composting, Portable Sawmilling, Bucking and Biogas	Gasification, Syngas and Pyrolysis and Carbonization

- Also, Ontario based inventors seem to have filed more patents than inventors in other Canadian provinces.

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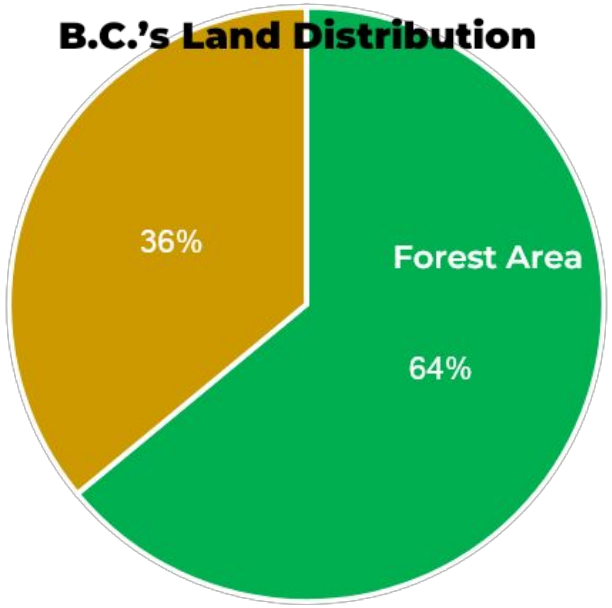

- B.C. has **more certified forest land** than any other jurisdiction in the world (with the exception of Canada as a whole) ensuring a sustainable biomass supply chain to support the bioeconomy.
- B.C. provides '**Indigenous Forest Bioeconomy Program' (IFBP)** that provides funding and support to Indigenous project partners that helps to maximize the use of forest biomass by making bioproducts.
- B.C. is identified as **top province** having the maximum number of **companies operating across** the value chain of the **forest bioeconomy** (also mentioned in 'VENTURES TO VALUE CHAINS' paper published by Foresight).
- B.C. **contributed $4.98 Billion** in Canadian's real **GDP in 2021**.

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Below are exemplary B.C. based key players across different sectors of forest bioeconomy:

Sustainable Forest Management

HUMMINGBIRD DRONES™

TREE TRACK INTELLIGENCE

MOSAIC FOREST MANAGEMENT

ZANZIBAR
Our business is about trees, our success is about people.

NORTHPAC FORESTRY GROUP

FTS
AN aem BRAND

Bioprocessing

andion

Benchmark Scientific

BryoSphere BIOTECHNOLOGIES

CelluloTech

CREATUS BIOSCIENCES

FuBiSol
Clean Energy and Products from Renewables

NanoTerraTech

KAM Biotechnology Ltd.
Leader In Industrial Microbiology

PERFORMANCE BioFilaments

plantee bioplastics inc

RhYme BIOTECHNOLOGY

FIT-NIR

Harmac MEDICAL PRODUCTS

Mercer

PAPER EXCELLENCE

CANFOR

CARRIER LUMBER

CONIFEX

Dunkley LUMBER LTD.

fybr
People. Places. Connected.

INTERFOR
Building Value.

KALESNIKOFF

AGI MILLTEC

SAN GROUP

The Teal-Jones Group
A Family Of Fine Forest Products

Sinclar Group FOREST PRODUCTS LTD.

TREECYCLE CANADA

West Fraser

fortress
Advanced Bioproducts

WFP Western Forest Products
DEFINING A HIGHER STANDARD

Value-added Products/Materials/

CANADIAN AgriChar
Manufacturer & Distribution of Biochar

BC BIOC

ECHO TECH CARBON CORP.
Solving for Co2-Climate Trend Setters

CONSOLIDATED BIOFUELS

reforus

LOW CARBON FUELS LTD.

Greenlane

HIGHBURY ENERGY

nexterra

PCS TECHNOLOGY

QUADROGEN

BAST FIBRE TECH

Bioform

BIOBOOST

COASTLAND Wood Industries Ltd.

FRASER WOOD residential

REFOREST DESIGN

CALMURA NATURAL WALLS

STRUCTURLAM MASS TIMBER CORPORATION
Intelligence In Wood

StructureCraft

drax

SEAGATE

TOLKO

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Acquisitions & Mergers

West Fraser | Spray Lake Sawmills

Union Park Capital | FTS (an aem brand)

BTG (A Voith Company) | FIT NIR

Interfor (Building Value) | Chaleur Forest Products

Western Forest Products | Calvert

Canfor | Millar Western

Paper Excellence | Resolute Forest Products

Interfor (Building Value) | Eacom Timber Corporation

Trimble | 3LOG Systems Inc

Partnerships & Joint Ventures

SWEN Capital Partners | Greenlane™

Village Farms | Quadrogen

Mercer | Resolute Forest Products

Plymouth Rock Technologie | Hummingbird Drones

Pinnacle Renewable Energy | Tolko

bid group | Canfor

andion | COGEI

Expander Energy Inc. | IMG Industries Inc

Investments

BIOCARBON

Bioform

Paper Excellence

andion

BAST FIBRE TECH

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CONCLUSIONS & RECOMMENDATIONS
Technology Whitespaces Actionable Insights – Potential Risks and Opportunities

FORESIGHT UnitedLex New Ventures BC

Technology Whitespaces are the opportunity areas, having low patenting activities with good future potential, therefore, can be considered for further research.

Following areas are recommended as technology whitespaces in this domain:

- Most of the countries have low filings in forest bioeconomy domain, therefore, patents can be filed in such countries (e.g., CA, BR, RU, JP, etc.).

- Further, few categories such as selective logging, site selection, etc. under forest harvest management have very low filings. Therefore, innovation research can be done in taxonomy nodes having low patent filings.

- Bioprocessing techniques such as Supercritical water gasification and Hydrothermal Liquification have low patent numbers, making it an area to explore further. In Canada, there are less patents in these nodes.

- Detailed whitespaces are provided in subsequent slides.

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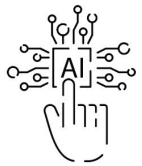
Forest Bioeconomy– Technology Whitespaces (1/3)

Technology Whitespace 1 – AI enabled automated tools/machines for harvesting/planting/forest monitoring operations

AI enabled automated tools/machines for harvesting/planting/forest monitoring operations – Implementation of AI and automation in tools and machinery in forestry operations such as harvesting, replanting, monitoring, etc.

ow

- There seem to be significant number of patent applications disclosing implementation of artificial intelligence in other areas. However, use of such techniques in forestry tools and machinery seem to be less explored. Exemplary patents – CN113989641A and CN208348856U.



Products & Services

Medium

- There are multiple research papers disclosing use of AI enabled machines for forestry operations.
- Swedish scientists have designed the world's first unmanned machine for autonomous forestry operations (Ref).

Market Scope

High

- The global Artificial Intelligence in Forestry and Wildlife Market size was valued at USD 1.95 billion in 2022 and is projected to expand at a compound annual growth rate (CAGR) of 27.8% during the forecast period, reaching a value of USD 13.87 billion by 2030.

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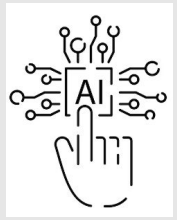
Forest Bioeconomy– Technology Whitespaces (2/3)

Technology Whitespace 2 – Digital Twinning and AI and in early fire detection



Digital Twinning and AI and in early fire detection – Digital Twinning and AI can be utilized to make interactive 3d models of the forest area, which can be used to detect spread of wildfire in real time.

Low

- There seem to be significant number of patent applications disclosing implementation of digital twinning in other areas e.g., manufacturing, industries, etc. . However, implementation of digital twinning in forest seems to be less explored. Few non-US patents disclose similar concept Exemplary patents – CN116139427A and KR10-2024-0068426

Products & Services

Low

- NASA's "Wildfire Digital Twin" project equipped firefighters and wildfire managers with a superior tool for monitoring wildfires and predicting harmful air pollution events and help researchers observe global wildfire trends more precisely. (Source)

Market Scope

High

- The digital twin market size was valued at $17.5 billion in 2023 and is expected to grow at a CAGR of 36.3% over the forecast period. (Source). It is expected that use of digital twins in forest management will also have similar growth rate in future.

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Forest Bioeconomy– Technology Whitespaces (3/3)

Technology Whitespace 3 – Bioprocessing techniques - Supercritical water gasification and Hydrothermal Liquification

Bioprocessing techniques - Supercritical water gasification and Hydrothermal Liquification – **Supercritical water gasification** converts forest biomass into syngas using water at supercritical conditions for efficient and clean energy production, while **hydrothermal liquefaction** transforms biomass into biocrude oil using high-temperature and high-pressure water, offering a sustainable pathway for biofuel production.

Low

- There seem to be less filing in these two sustainable processing techniques. Supercritical water gasification technique has only 14 patents, whereas as hydrothermal liquefaction has around 150+ patents, compared to other Bioprocessing techniques such as fermentation, hydrolysis and pyrolysis etc.
- In Canada also, fewer filings are observed in these nodes.

Products & Services

Medium

- There are several research papers that disclose advances in these bioprocessing techniques. For example, Hydrothermal Liquefaction of Biomass as one of the most promising alternatives for the synthesis of advanced liquid biofuels (Source) and advances in supercritical water gasification of lignocellulosic biomass for hydrogen production (Source)

Market Scope

High

- The bioprocessing market is projected to grow from US$ 25.35 billion in 2023 to US$ 72.55 billion by 2031 at CAGR of 14.0% by 2031. (Source). It is expected that use of these techniques will also have similar growth rate in future.

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Actionable Insights

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Basis the patent landscape study and market study, potential risks and opportunities have been recommended for Canada-based companies:

- **Potential Opportunities** – These include recommendations on what actions can be taken by Canada-based companies to strengthen their position in terms of valuable IP assets or in terms of value of products/services offered in comparison to their competitors.

- **Potential Risks** – These include indicators for potential risks that Canada-based companies might face if proper measures are not taken at the right time.

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Actionable Insights – Potential Opportunities

IP Protection

INSIGHTS

- Forest Bioeconomy domain has **high** future potential with significant revenue growth
- **New technologies are emerging** in sustainability and clean technology
- **Canada** has significantly **low filings** as compared to other countries

ACTIONABLES

- **Protect novel inventions** by filing patents
- Build a **defensive patent portfolio**
- Preferred jurisdictions for filings may be **CA, US and EP**
- Research in **whitespace areas** for invention harvesting

ADVANTAGES

- Gain **competitive edge** in Canadian or global market
- Helps to win **venture capital funding**
- Provides you **exclusive right to use** your invention
- Helps to **alleviate infringement risks**

Business Partnerships

INSIGHTS

- **Multiple start-ups** keep coming world-wide with unique solutions
- Patent **filings have been observed by Canada-based companies in the related technology areas**

ACTIONABLES

- **Collaborate with these companies** to explore new opportunities
- Explore options of **mergers, acquisition or partnerships** with such companies

ADVANTAGES

- Opportunity to **enhance services** by partnerships
- Provide **access to IP assets, additional resources and talent**
- **Portfolio divergence** to mitigate business risks

Actionable Insights – Potential Opportunities

Industry-Academia Collaboration

INSIGHTS

- ~ **5-6k patents** filed **by Universities** globally in each module
- **Canadian universities such as** University of Toronto, University of Western Ontario have filed patents in this domain

ACTIONABLES

- **Collaborate with the universities** to innovate and file patents.
- **License or purchase patents** filed by Universities

ADVANTAGES

- **Leverage research** done by **universities** to file patents
- **Establish innovation ecosystem**
- Generate **revenue** from patents

Patent and Technology Watch

INSIGHTS

- Patents **filings** are **increasing year on year**
- This is an **evolving area** where new technologies are innovated frequently

ACTIONABLES

- **Monitor newly filed/granted** patent assets
- Consider the most recent inventions to innovate
- Determine advancements in upcoming technologies

ADVANTAGES

- Awareness about latest or **future technology/IP trends**.
- **Updated competitive intelligence** and landscapes for **decision making**
- Knowledge about **potential risks and competitors**

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Actionable Insights – Potential Risks

Freedom to Operate Risks Globally

INSIGHTS

- **Strong patent protection in US, CN, EP**, etc.
- **Active patents** relevant to key categories such as wildfire management, forest monitoring, bioprocessing, etc. exist

PREVENTIVE MEASURES

- Perform **due diligence** before entering other countries
- **Use different strategy for each country** basis their patent laws and existence of patent assets

POTENTIAL RISKS

- **Difficult to launch** products/services in these jurisdictions
- **Risk of infringing** on others' patents
- **High competition** in other jurisdictions

Litigation Risk

INSIGHTS

- **Patent litigations** have been **observed in this technology area**
- Huge amount of **money spent in litigations**

PREVENTIVE MEASURES

- **Obtain patent licenses** for relevant products for preventing infringement risks
- Build a **defensive patent portfolio**

POTENTIAL RISKS

- **Potential risk on business sales if litigated** for infringement
- Potential **loss of revenue and customer base**
- **Difficult to re-gain the momentum** after the litigations

Actionable Insights – Potential Risks

Competitive Market

INSIGHTS

- **Multiple players operating** in this domain with different features
- **New start-ups coming** every year

PREVENTIVE MEASURES

- **Have unique features** in products/service **with proper IP protection**
- **Strategize business decisions** basis upcoming trends

POTENTIAL RISKS

- **Low growth rate** because of high competition
- **Difficult to get fundings,** etc. because of high competition

Adapting New Technologies

INSIGHTS

- Use of **new technologies** such as **artificial intelligence, blockchain, digital twinning, etc.**
- **Evolving Bioprocessing methods**

PREVENTIVE MEASURES

- **Keep your products/services upgraded** with new technologies
- **Use of automation** in most of the areas to reduce manual effort and improve efficiency

POTENTIAL RISKS

- Loss of market share because of lack of awareness about latest or **future technology/IP trends**.
- **Loss of customers** if products/solutions are not upgraded
- **Existing solutions** may become **obsolete**

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Appendix

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Appendix A - Taxonomy Definitions (1/13)

S. No.	Taxonomy Nodes	Definition
1	**Sustainable Forest Management**	Sustainable forest management refers to the practice of managing forests in a way that balances environmental, social, and economic considerations to ensure the long-term health and productivity of the forest ecosystem. This approach involves using forest resources in a manner that maintains biodiversity, supports local communities, preserves ecological functions, mitigates climate change, and meets present needs without compromising the ability of future generations to meet their own needs. Sustainable forest management typically involves strategies such as selective logging, reforestation, habitat preservation, and the promotion of responsible harvesting practices.
1.1	**Forest Monitoring**	Forest monitoring involves the observation and assessment of forest ecosystems to track changes over time and understand their health, dynamics, and trends. This process typically involves collecting data on various parameters such as tree species composition, forest structure, biodiversity, carbon storage, land use changes, disturbances (such as wildfires or logging), and other relevant factors. Forest monitoring often employs a combination of field surveys, remote sensing technologies (e.g., satellite imagery, LiDAR), and data analysis techniques to gather information at different spatial and temporal scales. The goal of forest monitoring is to provide valuable insights for informed decision-making in forest management, conservation, and policy development, ultimately contributing to the sustainable management and preservation of forest resources.
1.1.1	**Tree Health/Growth Assessment**	Tree health/growth assessment involves evaluating the overall condition of individual trees or stands of trees in a forest or other wooded areas. This assessment typically includes examining various indicators to determine the health and growth status of trees.
1.1.2	**Land Characteristics Assessment**	Forest land characteristics assessment involves the evaluation of various features and attributes of forested areas to understand their composition, structure, and ecological functions. For example, examination of the terrain features such as slope, aspect, elevation, and soil characteristics, which influence forest dynamics and ecosystem processes.
1.1.3	**Forest Inventory Management**	Forest inventory management involves the collection, analysis, and interpretation of data to assess the status, composition, structure, and productivity of forest resources within a specific area. For instance, managing the number of trees, type of trees etc.
1.1.4	**Natural Hazards Tracking**	Forest natural hazards tracking involves the continuous monitoring and assessment of natural events and phenomena that pose risks to forest ecosystems, resources, and surrounding communities. For instance, tracking of Wildfires, Insect Outbreaks and Diseases, Storms and Extreme Weather Events, Landslides and Soil Erosion, Floods and Hydrological Events and Climate Change Impacts.
1.1.4.1	**Natural Hazards Type**	The natural hazards tracking involves the monitoring and predicting different natural hazards like wildfire, storms, landslides/earthquake, hydrological events (drought and floods) and insect/diseases outbreaks.
1.1.4.1.1	**Wildfire**	The forest or wildfire detection involves real-time, alerts/warning information, tracking/monitoring of large fires and related activities for timely prevention and control of forest fires.

Appendix A - Taxonomy Definitions (2/13)

S. No.	Taxonomy Nodes	Definition
1.1.4.1.2	Storms	Detecting forest storms involve predicting early storms alerts/warning along with real-time monitoring of storms to mitigate the impacts of storms on forest ecosystems.
1.1.4.1.3	Landslides/Earthquakes	Predicting and monitoring earthquakes and landslides includes forecasting early warnings for potential landslides and earthquakes, along with continuously monitoring their impacts in real-time to prevent and manage hazardous situations effectively, particularly in forested areas.
1.1.4.1.4	Hydrological Events	Detecting hydrological events (drought or floods) involves drought or floods predictions along with real-time monitoring of hydrological events to mitigate the impacts of on forest ecosystems.
1.1.4.1.5	Insect/Diseases Outbreak	Detecting insect/diseases outbreak involves monitoring the forest ecosystem health in real-time for detecting and/or predicting any insect/diseases outbreak in the forest ecosystems to mitigate the impacts in advance.
1.1.4.2	Type of Natural Hazards Monitoring	The type of natural hazards monitoring involves real-time monitoring of hazards and predicting natural hazards in advance to mitigate the impact on forest ecosystem.
1.1.4.2.1	Real-Time Natural Hazards Monitoring	The real time natural hazards monitoring involves real-time data along with alerts/warning related to the natural hazards impacting the forests.
1.1.4.2.2	Predicting Natural Hazards	The predicting natural hazards involves utilizing various scientific methods and technologies to forecast the occurrence, intensity, and impacts of events such as earthquakes, landslides, hurricanes, floods, and wildfires.
1.1.5	Carbon Stock Tracking	Forest carbon footprint tracking involves the measurement, monitoring, and assessment of carbon emissions and sequestration associated with forest ecosystems and land use changes. This process typically includes Carbon Stock Assessment, Emissions Inventory, Carbon Sequestration Assessment, Land Use Change Analysis, Carbon Offsetting and Mitigation Strategies, etc.
1.2	Forest Monitoring Tools/Devices	Forest monitoring tools and devices are instruments and technologies used to collect data and gather information about forest ecosystems, including their composition, structure, health, and dynamics. These tools enable researchers, forest managers, and conservationists to assess various parameters and track changes over time.
1.2.1	GIS/Satellites	Satellite-based sensors capture images and data at different wavelengths to monitor forest cover, land use changes, deforestation, and forest disturbances over large spatial scales. GPS devices enable precise location tracking and mapping of forest features, facilitating field surveys, plot sampling, and spatial data collection.
1.2.2	Drone/UAV	Drones equipped with cameras, radars, or multispectral sensors can provide high-resolution aerial imagery and 3D mapping of the forested areas, allowing for detailed analysis of vegetation structure, health, and disturbances.

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Appendix A - Taxonomy Definitions (3/13)

S. No.	Taxonomy Nodes	Definition
1.2.3	LiDAR	Lidar sensor equipped with drones or ground/aerial vehicles for generating 3D maps and models of the forest areas, allowing for detailed analysis of structure of the forest vegetation.
1.3	Forest Replanting and Silviculture	Forest replanting, also known as reforestation or afforestation, refers to the deliberate planting of trees or regeneration of forest vegetation in areas where trees have been harvested, cleared, or otherwise removed. The goal of forest replanting is to restore forest cover, enhance biodiversity, protect soil and water resources, and provide ecosystem services such as carbon sequestration, wildlife habitat, and recreational opportunities. Silviculture is the science and practice of managing forest ecosystems to achieve specific objectives related to timber production, ecological conservation, and sustainable land use. Silvicultural practices are based on principles of forest ecology, biology, and economics and involve the manipulation of forest vegetation, structure, and composition to achieve desired outcomes.
1.3.1	Reforestation Management	Reforestation (Replanting/silviculture) management refers to the planning, implementation, and oversight of activities aimed at restoring forest vegetation and managing forest ecosystems to achieve specific objectives related to timber production, ecological conservation, and sustainable land use.
1.3.2	Tree Growth Enhancement	Replanting/silviculture site detection refers to the process of identifying and assessing suitable locations for reforestation, afforestation, or silvicultural treatments within forested landscapes. This involves the identification, evaluation, and selection of sites based on various criteria, including ecological suitability, management objectives, site conditions, and resource availability.
1.3.3	Machines for Replanting/Silviculture	Machines for replanting/silviculture are advanced mechanized equipment designed to streamline and optimize the process of tree planting, silvicultural treatments, and forest restoration activities. These machines leverage automation, robotics, and precision technology to increase efficiency, accuracy, and productivity in replanting and silviculture operations while reducing labor costs and improving environmental outcomes.
1.3.3.1	Autonomous Replanting/Silviculture machines	Autonomous replanting and silviculture machines are innovative technologies designed to automate the process of replanting trees and managing forests. These machines utilize various sensors, actuators, and onboard computing systems to perform tasks traditionally carried out by forestry workers. The automated machines can take safety measures for protecting wildlife, forest vegetation, and humans in the forest ecosystem.
1.3.3.2	AI-enabled Replanting/Silviculture machines	AI-enabled replanting and silviculture machines represent the next generation of forestry technology, leveraging artificial intelligence (AI) algorithms to optimize tree planting and forest management processes. These machines utilize advanced AI techniques to analyze data, make decisions, and adapt their operations in real-time.

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Appendix A - Taxonomy Definitions (4/13)

S. No.	Taxonomy Nodes	Definition
1.4	Harvesting Operations	Forest harvesting operations, also known as timber harvesting or logging, refer to the process of cutting, removing, and transporting trees from forested areas for commercial or industrial purposes.
1.4.1	Site Selection	Site selection in forest harvesting refers to the process of identifying and choosing specific locations within a forested area where timber extraction activities will take place. This decision-making process involves careful consideration of various factors including safety to ensure that harvesting operations are conducted effectively and sustainably.
1.4.2	Selective logging	Selective logging in forest harvesting, also known as selective cutting or selective thinning, is a timber extraction method that involves the removal of selected trees within a forest based on different parameters such as diameter, height, or species, etc. Selective logging aims to minimize the ecological impact on the forest ecosystem by maintaining its structure, biodiversity, and ecological functions.
1.4.3	Harvest Residuals Management	Forest harvest residuals management refers to the handling and utilization of the leftover biomass and woody materials remaining in a forest after harvesting operations. These residuals, also known as logging residues or slash, include branches, tree tops, bark, stumps, and other woody debris that are not utilized as primary timber products. Effective management of forest harvest residuals is essential for maximizing resource utilization, minimizing waste, and mitigating environmental impacts.
1.4.4	Direction felling and Sectional Dismantling	Direction felling involves deliberately aiming the falling direction of a tree to a specific target area by making strategic cuts on the trunk. Sectional dismantling, also known as controlled or partial felling, involves cutting a tree into sections, or "lifts," from the top down, rather than felling it in one piece.
1.4.5	Logistics	Logistics in forest harvesting refers to the planning, coordination, and management of resources, activities, and operations involved in the extraction and transportation of timber from forested areas to processing facilities or markets. It encompasses a range of activities aimed at ensuring the efficient and timely movement of harvested wood products while optimizing resource utilization, minimizing costs, and mitigating environmental impacts.
1.4.5.1	Harvesting Route Planning	Sustainable harvesting route planning involves the strategic design and selection of transportation routes for wood/timber extraction from forested areas that maximize efficiency while minimizing environmental impacts and promoting sustainable forest management practices.
1.4.5.2	Cable Logging Systems	Cable logging systems, also known as cable yarding systems or skyline logging systems, are methods used in forest harvesting to extract timber from steep or difficult terrain where conventional ground-based equipment may be impractical or environmentally sensitive. Cable logging systems utilize cables, winches, and rigging to lift, move, and transport logs from the harvest site to a central landing area or roadside for processing and transportation.
1.4.6	Harvesting Machines	Harvesting machines, also known as mechanized harvesting equipment or forestry harvesters, are advanced machinery used in the logging industry to mechanize and streamline the process of tree felling, delimbing, bucking, and processing. These machines are designed to increase efficiency, productivity, and safety in timber harvesting operations while reducing reliance on manual labor and improving overall operational performance. To name a few, these are Felling Head, Delimbing and Bucking Arms, Grapple or Clamshell, Hydraulic Systems, etc.

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Appendix A - Taxonomy Definitions (5/13)

S. No.	Taxonomy Nodes	Definition
1.4.6.1	**Autonomous Harvesting Machines**	Autonomous harvesting machines are innovative technologies designed to automate the process of log harvesting from the forests. These machines utilize various sensors, actuators, and onboard computing systems to perform tasks traditionally carried out by forestry workers. The automated machines can take safety measures for protecting wildlife, forest vegetation, and humans in the forest ecosystem.
1.4.6.2	**AI-enabled harvesting machines**	AI-enabled harvesting machines represent the next generation of forestry technology, leveraging artificial intelligence (AI) algorithms to optimize log harvesting processes. These machines utilize advanced AI techniques to analyze data, make decisions, and adapt their operations in real-time.
2	**Sustainable Processing**	Sustainable processing steps for the conversion of biomass and waste from forests into value-added products involve the utilization of forest residues, woody biomass, and other by-products to create economically viable products while minimizing environmental impacts and promoting resource efficiency. These steps aim to maximize the utilization of available biomass resources, reduce waste, and support the sustainable management of forest ecosystems.
2.1	**Bioprocessing**	Forest Bioprocessing refers to the utilization of biological processes, such as fermentation, enzymatic reactions, and microbial conversion, to transform forest-derived biomass into value-added products and bio-based materials. This approach leverages the natural capabilities of microorganisms, enzymes, and biochemical pathways to convert lignocellulosic biomass, including wood, bark, branches, and forest residues, into a range of bioproducts, biofuels, and biochemicals.
2.1.1	**Biological Techniques**	Biological techniques for forest Bioprocessing involve the utilization of living organisms, such as microorganisms, enzymes, and fungi, to convert forest-derived biomass into valuable products and bio-based materials. These techniques harness the natural capabilities of biological systems to break down complex biomass components, such as cellulose, hemicellulose, and lignin, and transform them into biofuels, biochemicals, and bioproducts.
2.1.1.2	**Fermentation**	Fermentation processes utilize microorganisms, such as bacteria, yeast, or fungi, to metabolize sugars derived from biomass hydrolysis into biofuels, biochemicals, or biopolymers. Common fermentation products include ethanol, butanol, lactic acid, succinic acid, enzymes, and microbial biomass.
2.1.1.2	**Anaerobic and Aerobic Digestion/Composting**	Anaerobic digestion employs microbial consortia to degrade organic matter present in forest biomass under oxygen-free conditions, producing biogas (methane and carbon dioxide) as a renewable energy source and digestate as a soil amendment. Anaerobic digestion is suitable for treating organic residues and waste streams from forest processing operations. Anaerobic digestion is a biological process that occurs in the absence of oxygen, where microorganisms break down organic matter into biogas and digestate.

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Appendix A - Taxonomy Definitions (6/13)

S. No.	Taxonomy Nodes	Definition
2.1.2	Thermo-chemical Techniques	Thermo-chemical techniques for forest bioprocessing involve the use of heat and chemical reactions to convert forest biomass into valuable products such as biofuels, biochemicals, and bioproducts. These techniques are typically used to break down complex biomass components such as cellulose, hemicellulose, and lignin into simpler compounds through various thermal and chemical processes.
2.1.2.1	Pyrolysis and Carbonization	Pyrolysis and carbonization are thermochemical processes used to convert biomass into biochar, Bio oil, and syngas, among other products, through the application of heat in the absence or limited presence of oxygen.
2.1.2.2	Hydrothermal liquefaction	A thermochemical conversion process that transforms wet biomass into biocrude oil through the application of heat, pressure, and water in a subcritical or supercritical water environment.
2.1.2.3	Gasification	A thermochemical process that converts carbonaceous materials, such as biomass or coal, into synthesis gas (syngas) by reacting them with a controlled amount of oxygen or steam at high temperatures.
2.1.2.4	Torrefaction	A mild thermal treatment process that involves heating biomass in the absence of oxygen to remove moisture and volatile compounds, leaving behind a stable, high-energy-density solid fuel called torrefied biomass or bio coal.
2.1.3	Biochemical Techniques	Biological methods or processes used to manipulate biological systems, such as enzymes or microorganisms, to convert biomass into biofuels, biochemicals, or bioproducts.
2.1.3.1	Hydrolysis	A chemical reaction in which a compound is broken down by the addition of water molecules, often used in the conversion of biomass into sugars for biofuel production.
2.1.3.2	Transesterification	A chemical reaction in which triglycerides (e.g., vegetable oils or animal fats) react with an alcohol (e.g., methanol or ethanol) to form fatty acid esters (e.g., biodiesel) and glycerol.
2.1.3.3	Supercritical water gasification	A thermochemical process that uses supercritical water (water at high temperature and pressure) to convert wet biomass into syngas, hydrogen, and other valuable products.
2.1.4	Physical Techniques	Methods or processes that involve physical changes or treatments to biomass or materials. Only sustainable techniques are considered.
2.1.4.1	Steam-Explosion	A physical pretreatment method that involves the rapid release of steam followed by a sudden decompression, which disrupts the structure of biomass and enhances its susceptibility to enzymatic hydrolysis.
2.1.4.2	Fractionation	A process for converting lignocellulosic feedstocks into three discrete fractions of lignin, cellulose and hemicelluloses.
2.1.4.3	Pelletizing	A process of the formation of cylindrical biomass pellets by drying it and compressing it under intense pressure.
2.1.4.4	Briquetting	A process that compresses biomass or waste materials into dense, solid fuel briquettes or pellets for use in heating or power generation.

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Appendix A - Taxonomy Definitions (7/13)

S. No.	Taxonomy Nodes	Definition
2.2	**Processes in Paper and Pulp Mills**	Industrial facilities that process wood or other fibrous materials to produce paper, pulp, and related products.
2.2.1	**Sustainable processes**	Methods, techniques, or practices that minimize environmental impact, conserve resources, and promote social responsibility throughout their lifecycle.
2.2.1.1	**Water Conservation**	Practices or measures aimed at reducing water usage, minimizing waste, and preserving water resources.
2.2.1.2	**Chemical Recovery and Reuse**	Methods or systems used to recover and reuse chemicals or by-products generated in industrial processes.
2.2.1.3	**Energy-Efficient Technologies**	Technologies or practices designed to optimize energy use, reduce energy consumption, and improve energy efficiency.
2.2.1.4	**Treatment of Hazardous Pollutants**	Methods or processes used to remove or neutralize hazardous pollutants in paper and pulp making processes.
2.2.1.5	**Waste recycling and Reuse**	Practices or processes that involve the collection, sorting, processing, and reuse of waste materials to minimize environmental impact and conserve resources in paper and pulp making processes.
2.2.2	**Pulp and Paper Processing Techniques**	Methods or techniques (sustainable) used to transform pulp wood into pulp and paper.
2.2.2.1	**Collection and Sorting**	Method or process used for sorting forest waste or wood processing residue, which can include branches, bark, sawdust, and other residues from logging and forestry operations, is collected and sorted.
2.2.2.2	**Chipping or Grinding**	Process involves the chipping or grounding the sorted wood residue or forest waste into smaller pieces to increases the surface area of the material, making it easier to process.
2.2.2.3	**Pulping**	Process of separating fibers from the lignin and other components by processing the chipped or ground forest waste.
2.2.2.3.1	**Mechanical Pulping**	A process that uses mechanical forces, such as grinding or pressing, to separate fibers from wood or other fibrous materials for paper production.
2.2.2.3.2	**Biochemical Pulping**	A pulping process that uses enzymes or microorganisms to break down lignin and separate fibers from wood or other biomass materials.
2.2.2.4	**Bleaching**	The process of removing to any remaining lignin and other impurities from the pulp.
2.2.2.4.1	**Enzymatic Bleaching**	A bleaching process that uses enzymes to remove lignin and brighten pulp fibers in the papermaking process.
2.2.2.5	**Forming Techniques**	The process of pouring pulp slurry onto a wire mesh conveyor, allowing water to drain through while retaining the fibers to form a wet paper sheet, and then the wet paper sheet is passed through heated drying cylinders to evaporate the remaining moisture, resulting in a dry paper sheet ready for finishing.

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Appendix A - Taxonomy Definitions (8/13)

S. No.	Taxonomy Nodes	Definition
2.3	Saw-Mills	Facilities that process logs or timber into lumber or wood products using sawing, cutting, and milling operations.
2.3.1	Sustainable processes	List of sustainable processes in Saw-Mills.
2.3.1.2	Portable saw-milling	A mobile or transportable saw-mill used to process logs or timber into lumber or wood products at different locations.
2.3.1.3	Advanced Sawing Equipment	High-tech or precision equipment used in saw-mills for cutting, sawing, and processing timber.
2.3.1.4	Waste Management Techniques	Methods or practices used to manage, treat, or dispose of waste materials in an environmentally responsible manner.
2.3.1.5	Emission Control Technologies	Technologies or systems used to reduce or control emissions of pollutants, such as particulate matter, gases, or volatile organic compounds.
2.3.1.6	Integration with Renewable Energy Systems	Incorporating renewable energy sources, such as solar, wind, or biomass, into industrial processes or systems to reduce reliance on fossil fuels and minimize environmental impact.
2.3.2	Saw-Mills Processing Techniques	Methods or techniques (sustainable) used in Saw-Mills.
2.3.2.1	Sorting and Scaling	The process involves sorting and scaling logs based on species, size, quality characteristics for optimizing the processing sequence and identifying logs suitable for different end products.
2.3.2.2	Debarking	The process involves the removal of outer bark layer via mechanically or biochemical to prepare the logs for further processing
2.3.2.3	Bucking	The process of cutting logs into shorter lengths based on the intended use and processing equipment's capacity.
2.3.2.4	Headrig Sawing	The logs are fed into a primary breakdown machine called a headrig saw, which makes the initial cuts to produce rough lumber. This process involve different sawing techniques such as plain sawing, quarter sawing, or rift sawing.
2.3.2.5	Edging and Trimming	The process involves removing irregularities, defects, excess material and creating straight edges on the lumbers obtained after cutting the logs.
2.3.2.6	Planing, Moulding and Profiling	The process involves smoothen the surfaces, achieving uniform thickness, and processing the lumber through moulders or profiling machines to add decorative or functional profiles.
2.3.2.7	Drying	The process of drying limber in kilns (Integration with Renewable Energy Systems) to reduce moisture content to the desired level. Kiln schedules are carefully controlled to avoid defects such as warping, checking, and case hardening.
2.4	Manufacturing Engineered Wood Products	Processes or techniques used to manufacture wood-based engineered products, such as plywood, particleboard, or laminated timber.
2.4.1	Hot Pressing	A process used in the manufacturing of wood-based panels or engineered wood products that involves pressing and bonding layers of wood or wood particles under heat and pressure.
2.4.2	Cold Pressing	A pressing process used in the manufacturing of wood-based panels or engineered wood products that does not involve the application of heat.

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Appendix A - Taxonomy Definitions (9/13)

S. No.	Taxonomy Nodes	Definition
3	Value-Added Products/Materials/Applications	After processing of forest raw materials, list of products, materials, or applications that offer additional benefits or features beyond their basic functions, such as enhanced performance, durability, or sustainability.
3.1	Wood Pellets	Small, cylindrical pellets made from compressed wood or biomass materials, used as a renewable fuel for heating or power generation.
3.1.1	Torrefied Pellets	Wood pellets produced through the torrefaction process, which increases their energy density and stability.
3.1.2	Steam Explosion Pellets	Wood pellets produced using the steam explosion process, which improves their digestibility and suitability for various applications.
3.2	Engineered Wood Products	Products made from wood or wood fibers that have been engineered or processed to improve their strength, durability, or other properties.
3.2.1	Particleboard	A composite wood panel made from wood particles or fibers bonded together with resin under heat and pressure.
3.2.2	Oriented Strand Board (OSB)	A type of engineered wood panel made from oriented strands or flakes of wood bonded together with resin.
3.2.3	Glulam (Glued Laminated Timber)	Structural timber beams or columns made by gluing together laminations of wood with adhesive under pressure.
3.2.4	Thermal Modified Timber	Wood that has been treated with heat to improve its dimensional stability, decay resistance, and durability.
3.2.5	Medium Density Fiberboard (MDF)	A type of engineered wood product made from wood fibers bonded together with resin under heat and pressure.
3.2.6	Plywood	A panel made from thin layers of wood veneer glued together with alternating grain directions to improve strength and stability.
3.2.7	Wood fiber-glass	Composite material made from wood fibers and fiberglass, used in construction and automotive applications.
3.2.8	Cross-Laminated Timber (CLT)	A type of engineered wood product made from layers of wood panels glued together with alternating grain directions to improve strength and stiffness.
3.2.9	Laminated Veneer Lumber (LVL)	A structural engineered wood product made from thin layers of wood veneer glued together under pressure to form beams or columns.
3.3	Biofuels	Fuels derived from biomass, such as ethanol, biodiesel, and Bio oil, used as alternatives to fossil fuels for transportation or heating.
3.3.1	Liquid Fuel	Biofuels that are in liquid form, such as ethanol, biodiesel, and Bio oil.
3.3.1.1	Ethanol	A biofuel produced by fermenting sugars or starches derived from biomass, used as a renewable fuel additive or substitute for gasoline.
3.3.1.2	Biodiesel	A renewable diesel fuel made from vegetable oils, animal fats, or recycled cooking oil through transesterification.
3.3.1.3	Bio oil	A liquid fuel produced from the pyrolysis or liquefaction of biomass, used as a feedstock for biofuels or biochemicals.
3.3.1.4	Bio-crude	A crude oil substitute produced from the pyrolysis or liquefaction of biomass, used as a feedstock for refining into transportation fuels or chemicals.

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Appendix A - Taxonomy Definitions (10/13)

S. No.	Taxonomy Nodes	Definition
3.3.1.5	Bio gasoline	A gasoline substitute produced from bio-oil or other bio-based feedstocks, used as a renewable fuel for internal combustion engines.
3.3.1.6	Bio ethers	Oxygenated compounds derived from biomass, used as fuel additives or blending agents for gasoline or diesel fuels.
3.3.1.7	Aviation biofuel	Biofuels produced from renewable sources, such as algae or biomass, used as a sustainable alternative to conventional jet fuel in aviation.
3.3.2	Gaseous Fuel	Biofuels that are in gaseous form, such as biogas or syngas, used for heating, power generation, or transportation.
3.3.2.1	Biogas	A renewable gas produced by the anaerobic digestion of organic matter, used as a fuel for heating, electricity generation, or vehicle fuel.
3.3.2.2	Syngas	A synthetic gas mixture composed of hydrogen, carbon monoxide, and other gases produced by the gasification of biomass or coal, used as a feedstock for chemical synthesis or fuel production.
3.3.3	Solid Fuel	Biofuels that are in solid form, such as wood pellets or biochar, used for heating or power generation.
3.3.3.1	Biochar and solid carbon	Carbon-rich materials produced from the pyrolysis or carbonization of biomass, used as soil amendments, carbon sequestration agents, or solid fuels.
3.3.3.2	Wood-Based Biofuels	Biofuels produced from wood or wood-derived biomass, such as wood pellets, torrefied pellets, or pyrolysis oil.
3.4	Biomaterials	Materials derived from renewable biomass sources, such as wood, plants, or agricultural residues, used for various applications in industries such as construction, packaging, and healthcare.
3.4.1	Wood-Based Biomaterials	Biomaterials derived from wood or wood fibers, such as cellulose nanocrystals, lignin-based polymers, or wood composites.
3.4.1.1	Wood Fiber	Fibrous material obtained from wood or wood pulp, used as a reinforcement or filler in composite materials, papermaking, or textile production.
3.4.1.2	Lignin	A complex polymer found in the cell walls of plants, particularly abundant in wood, used as a binder, filler, or feedstock for the production of chemicals, materials, or biofuels.
3.4.1.3	Cellulose Nanocrystals (CNC)	Nano-sized crystalline particles derived from cellulose fibers, used as a reinforcing agent in composite materials, films, or coatings.
3.4.2	Forest Residue-Based Biomaterials	Biomaterials derived from forest residues, such as bark, sawdust, or branches, used for various applications in construction, packaging, or bioenergy production.
3.4.2.1	Lignocellulosic Biomass	Biomass composed of cellulose, hemicellulose, and lignin, found in plant cell walls and commonly used as a feedstock for biofuel production or biomaterials.
3.4.2.2	Biochar	Charcoal-like material produced from the pyrolysis or carbonization of biomass, used as a soil amendment to improve soil fertility, water retention, and carbon sequestration.
3.4.3	Natural Polymers	Polymers derived from renewable resources, such as starch, cellulose, or proteins, used in various applications such as packaging, textiles, or biomedical materials.

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Appendix A - Taxonomy Definitions (11/13)

S. No.	Taxonomy Nodes	Definition
3.4.3.1	Lignin-Based Polymers	Polymers derived from lignin, a natural polymer found in wood and plant cell walls, used as a binder, adhesive, or additive in composite materials, coatings, or adhesives.
3.4.3.2	Chitosan from Fungi	Chitosan, a biopolymer derived from the shells of crustaceans or fungi, used in various applications such as wound healing, drug delivery, or wastewater treatment.
3.4.4	Extracts and Essential Oils	Natural compounds extracted from plants, such as terpenes, tannins, or essential oils, used in cosmetics, aromatherapy, pharmaceuticals, or food flavoring.
3.4.4.1	Terpenes	Aromatic compounds found in plant essential oils, used as fragrances, solvents, or chemical intermediates in industries such as cosmetics, pharmaceuticals, or agriculture.
3.4.4.2	Tannins	Polyphenolic compounds found in plant tissues, such as bark or leaves, used in tanning leather, wood preservation, or as antioxidants in food and beverages.
3.4.5	Mushroom-Based Biomaterials	Biomaterials derived from mushrooms or fungal mycelium, used in various applications such as packaging, construction, or biodegradable materials.
3.4.5.1	Mycelium Composites	Mycelium composites represent a novel material created by blending mycelium, which resembles the root structures of fungi, with organic waste or agricultural residues.
3.4.6	Applications	Practical uses or potential uses of biofuels in various industries or sectors.
3.4.6.1	Aviation and Automotive Parts	Components or parts used in aircraft or automotive vehicles, including structures, interiors, or propulsion systems, made from biomaterials or bio-based composites.
3.4.6.2	Textiles	Fabrics, fibers, or materials used for clothing, furnishings, or industrial applications, made from natural or synthetic fibers, including biomaterials or bio-based fibers.
3.4.6.3	Packaging	Materials used for wrapping, protecting, or containing products, including biomaterials or bio-based packaging materials.
3.4.6.4	Consumer Goods	Products or items used by consumers in daily life, including electronics, appliances, or household products, made from biomaterials or bio-based materials.
3.5	Biochemicals	Chemical compounds derived from living organisms, typically produced through biological processes or extracted from biomass, and used in various industrial, agricultural, pharmaceutical, and consumer applications.
3.5.1	Lignin-Derived Chemicals	Chemical compounds obtained from lignin, a complex polymer found in the cell walls of plants, often used as raw materials or intermediates in the production of adhesives, resins, and specialty chemicals.
3.5.1.1	Vanillin	A natural compound and primary component of vanilla bean extract, commonly used as a flavoring agent in food, beverages, and fragrances.
3.5.1.2	Phenolic Compounds	A diverse group of organic compounds characterized by the presence of one or more hydroxyl groups attached to an aromatic ring structure, often found in plants and used for their antioxidant, antimicrobial, and medicinal properties.

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Appendix A - Taxonomy Definitions (12/13)

S. No.	Taxonomy Nodes	Definition
3.5.1.3	Aromatic Chemicals	Aromatic chemicals derived from lignin, such as benzene, toluene, xylene, and cresols, can be used as feedstocks for the production of plastics, synthetic fibers, solvents, and specialty chemicals.
3.5.1.4	Polyols	Lignin-derived polyols can be used as substitutes for petroleum-based polyols in the production of polyurethane foams, coatings, adhesives, and elastomers, reducing dependency on fossil fuels and providing environmental benefits.
3.5.1.5	Surfactants	Lignin-derived surfactants can be used in various applications, including detergents, emulsifiers, dispersants, and foaming agents.
3.5.2	Terpenes and Terpenoids	A large class of natural compounds synthesized by plants and some microorganisms, consisting of repeating isoprene units, commonly used in fragrances, flavors, pharmaceuticals, and industrial applications.
3.5.2.1	α-Pinene and β-Pinene	Two common terpenes found in the essential oils of various plants, including pine trees, used as fragrances, solvents, and chemical intermediates in industries such as cosmetics, pharmaceuticals, and cleaning products.
3.5.2.2	Rosin and Turpentine	Natural resins obtained from pine trees, with rosin being a solid resin and turpentine being a volatile oil, used in a wide range of applications including adhesives, varnishes, inks, and solvents.
3.5.2.3	Carotenoids	Pigments found in plants, algae, and some bacteria, responsible for the yellow, orange, and red colors of fruits and vegetables, with applications in food coloring, cosmetics, and nutritional supplements.
3.5.3	Tannins	Polyphenolic compounds found in plant tissues, particularly in bark, leaves, and fruits, used for tanning leather, dyeing fabrics, and as antioxidants in food and beverages.
3.5.3.1	Tannic Acid	A type of tannin compound found in various plants, especially in gallnuts and oak bark, used in tanning leather, ink production, and as a mordant in dyeing textiles.
3.5.4	Essential Oils	Highly concentrated liquids extracted from plant materials, containing volatile aromatic compounds responsible for the characteristic odor and flavor of the plant, commonly used in aromatherapy, perfumery, and natural remedies.
3.5.4.1	Eucalyptus Oil	Essential oil extracted from the leaves of eucalyptus trees, known for its medicinal properties such as relieving respiratory symptoms and soothing sore muscles, often used in pharmaceuticals, cosmetics, and aromatherapy.
3.5.4.2	Pine Oil	Essential oil obtained from pine needles or wood, valued for its fresh, woodsy scent and antiseptic properties, used in cleaning products, air fresheners, and personal care items.
3.5.5	Bio-based Polymers	Polymers derived from renewable biomass sources, such as plants or microorganisms, used as alternatives to conventional petroleum-based plastics in various applications, including packaging, textiles, and biomedical devices.
3.5.5.1	Cellulose Acetate	A bio-based polymer derived from cellulose, commonly used in the production of films, fibers, and plastics, with applications in photography, textiles, and consumer goods.
3.5.6	Applications	Practical uses or potential uses of biochemicals in specific industries, sectors, or contexts.

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Appendix A - Taxonomy Definitions (13/13)

S. No.	Taxonomy Nodes	Definition
3.5.6.1	Cosmetics	Products used for enhancing or altering the appearance of the face, skin, hair, or body, including skincare, makeup, haircare, and fragrances.
3.5.6.2	Healthcare	Goods, services, and technologies related to the maintenance, improvement, and treatment of physical and mental health, including medical devices, pharmaceuticals, and healthcare facilities.
3.5.6.3	Fertilizer	Substances applied to soil or plants to promote growth, yield, and health by providing essential nutrients such as nitrogen, phosphorus, and potassium.
3.5.6.4	Paints, Glues, Resins	Chemical formulations used for coating surfaces, adhering materials together, or providing protective and decorative finishes, commonly used in construction, automotive, and manufacturing industries.
3.6	Biomass heat and power generation	The use of biomass, such as wood, agricultural residues, or organic waste, as a fuel source for heating buildings or generating electricity through combustion, gasification, or anaerobic digestion processes.
3.6.1	Heating Applications	The use of heat energy for residential, commercial, or industrial purposes, including space heating, water heating, and process heating, often provided by boilers, furnaces, or heat pumps.
3.6.2	Power Generation	The production of electricity from various energy sources, including fossil fuels, nuclear energy, renewables, and biomass, using steam turbines, generators, or other technologies.

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Appendix B - Country Codes

Country Code	Country Name
CN	China
KR	Korea
US	United States
IN	India
EP	Europe
RU	Russia
AR	Argentina
BY	Belarus
ID	Indonesia
MX	Mexico
WO	WIPO
JP	Japan
BR	Brazil

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Appendix C - Inclusions and Exclusions

Inclusions

- Value-chain nodes as mentioned in the paper Canada's VENTURES TO VALUE CHAINS - FOREST BIOECONOMY
- Sustainable processes/methodologies in each of the nodes.
- The scope for Module C Value-Added Products/Materials/Applications encompasses products and materials derived from forest biomass, forest wastes, mill residuals, and other related sources. These products are developed using the sustainable Bioprocessing techniques established in Module B.

Exclusions

- Concepts not falling within the scope of the categories defined in the taxonomies.
- The patent publications that disclose similar concepts in agricultural or farm field and may not be applicable to forest land.
- The patent publications that generically disclose use of drones, satellites, etc. to map or monitor geographic areas but do not disclose applicability in forest bioeconomy.
- Patents that do not reference the processing of end-products and materials using relevant sources such as forest biomass, mill residuals and other related sources via sustainable Bioprocessing techniques.
- Patents related to compositions of the biomaterials, use-cases for biomaterials (such as food additives, pesticides, surface cleaners, detergents, foundry

Assumptions

- Number of patents/ published applications filed in 2022/2023/2024 may be more than this document shows, as some of the applications filed during this period may not have been published yet.
- All alive patents/publications are considered for the analysis. Alive/Dead is considered based on data provided by Derwent Innovation.
- The analysis is primarily done on Title, Abstract and Claims. Support is taken from the description for some taxonomy nodes.
- Producing biomass, bioproducts, etc. from forest residues is covered in module B, therefore, we have not covered that in module A under Harvesting Residues Management.

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