# 2025 Forest Bioeconomy Landscape Study (Refresh)

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# Introduction

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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 the value chain of forest bioeconomy (a snapshot of the value chain is provided in the next slide). Based on the value chain, the report has been divided into the below three modules:

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

This report analyzes 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.

This report is primarily divided into the following sections:

- Technology Taxonomy
- Patent Insights
- Patent Litigations
- Market Insights
  - Key Players
  - Key Mergers and Acquisitions
  - Key Partnerships
- British Columbia-based Insights
- Conclusion and Recommendations
- Appendix

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# Value Chain

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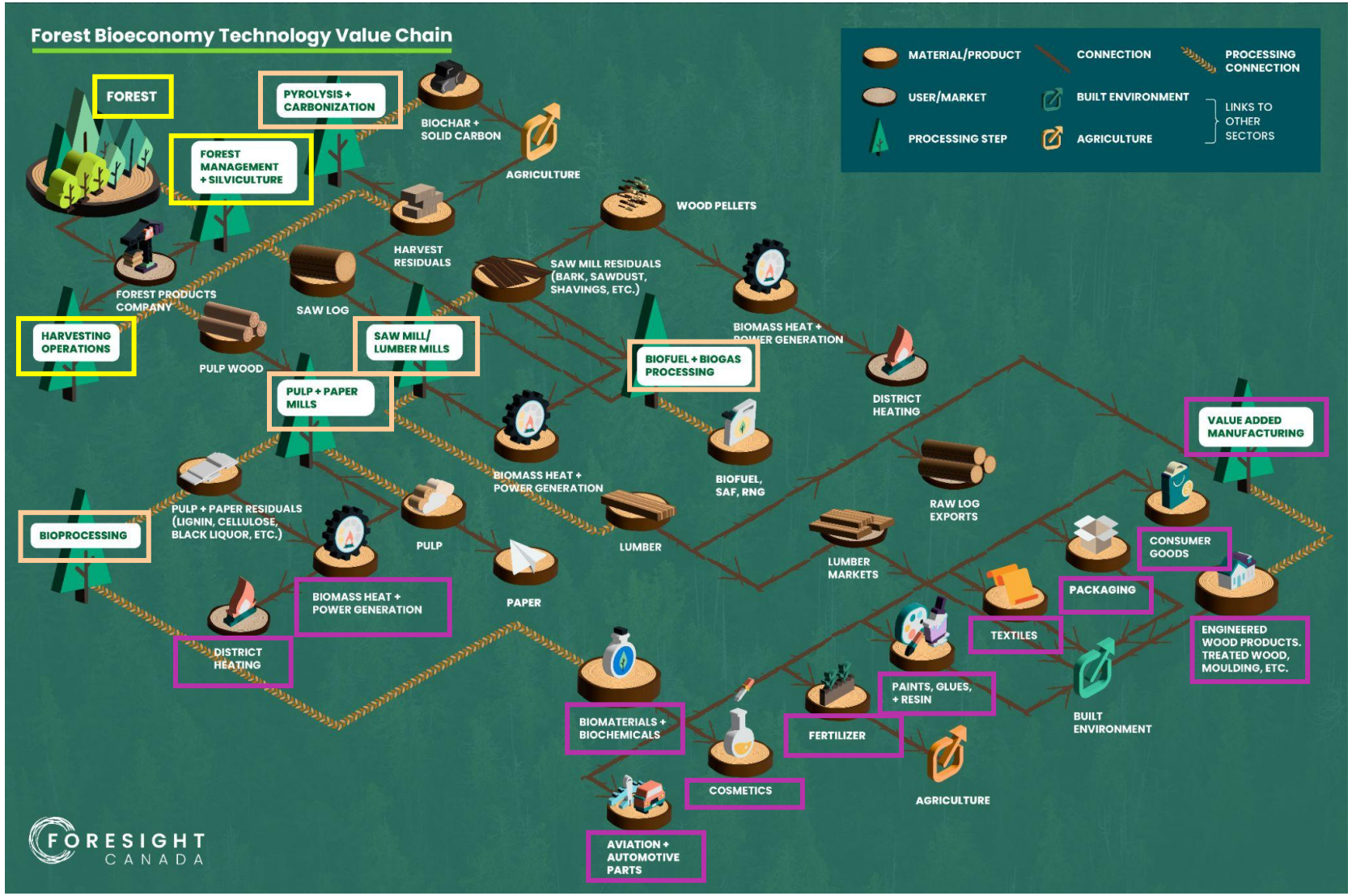
# Forest Bioeconomy- Value Chain (1/2)




**Module A: Sustainable Forest Management**

**Module B: Sustainable Processing**

**Module C: Value-added Products/ Materials/Applications**

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# Forest Bioeconomy- Value Chain (2/2)

## 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 promoting resource efficiency. This includes Processes in Paper and Pulp Mills, Saw-Mills, Bioprocesses to convert biomass and methods to manufacture Engineered Wood Products.

## Module C: Value-added Products/ Materials/Applications

Bioproducts are derived from forest biomass that offers 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

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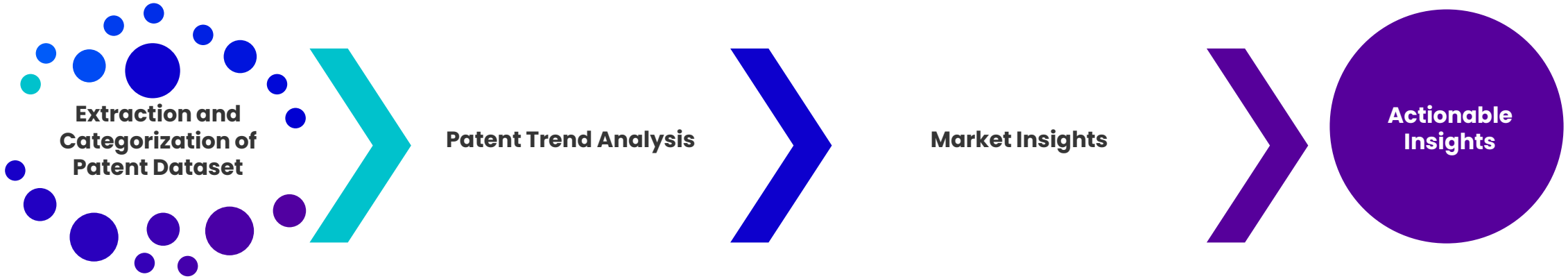
# Methodology

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 Canadian companies. The methodology includes the following steps:




**Step 1:** Used various search strategies (keywords, classes, citations, semantics 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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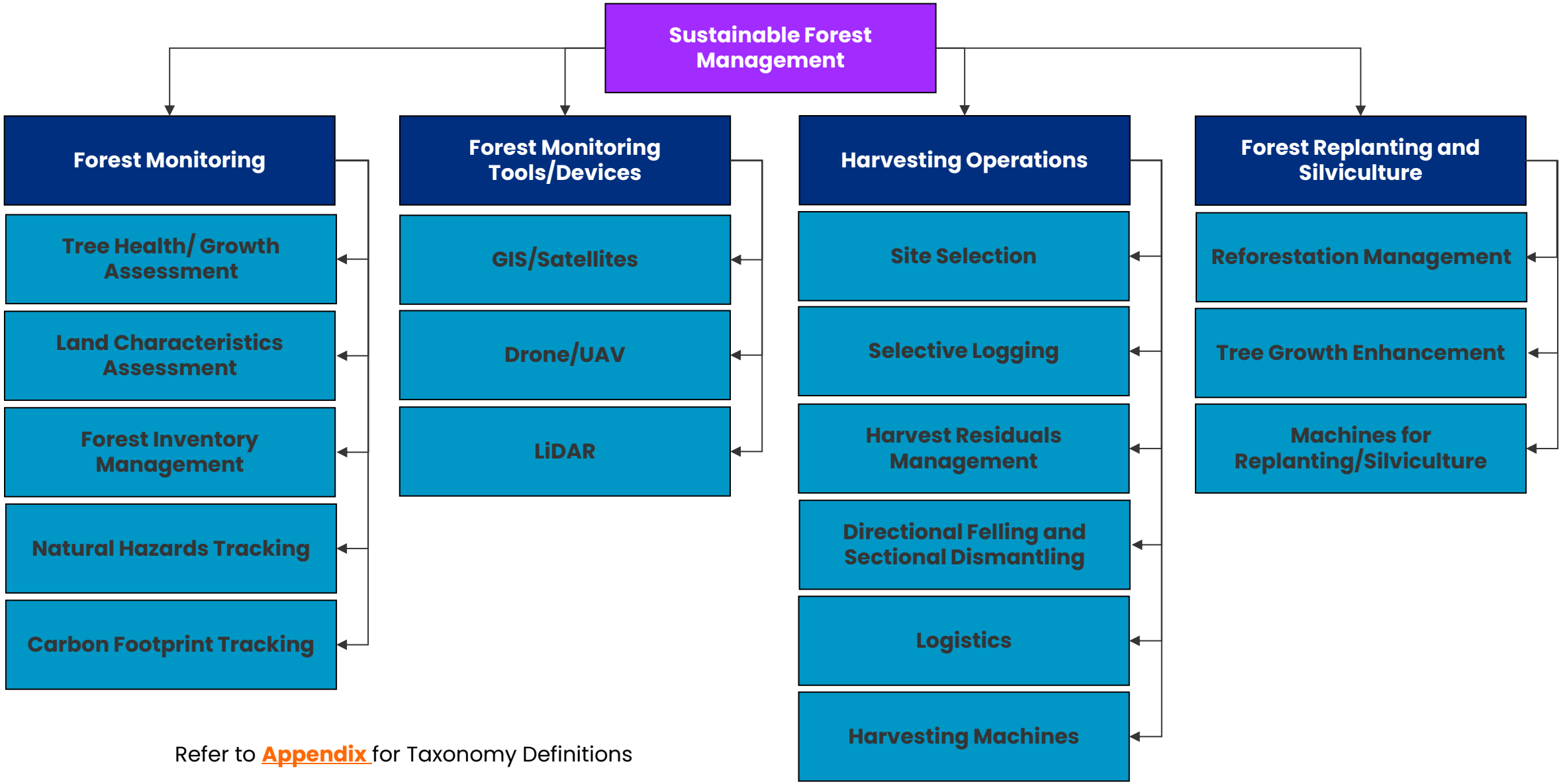
# Technology Taxonomy – Module A – Sustainable Forest Management (1/3)




Refer to **Appendix** for Taxonomy Definitions

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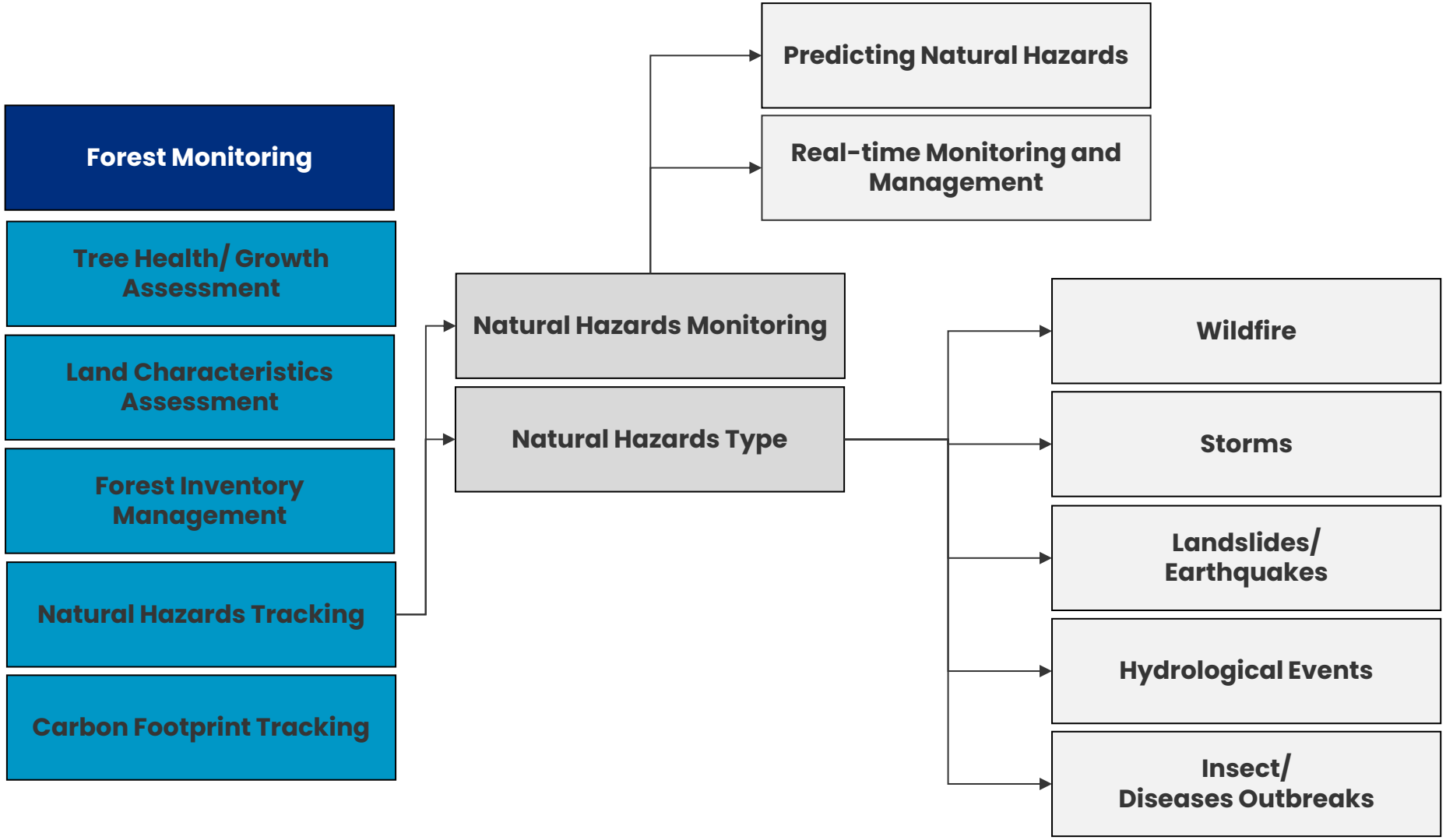
# Technology Taxonomy – Module A – Sustainable Forest Management (2/3)




Refer to **Appendix** for Taxonomy Definitions

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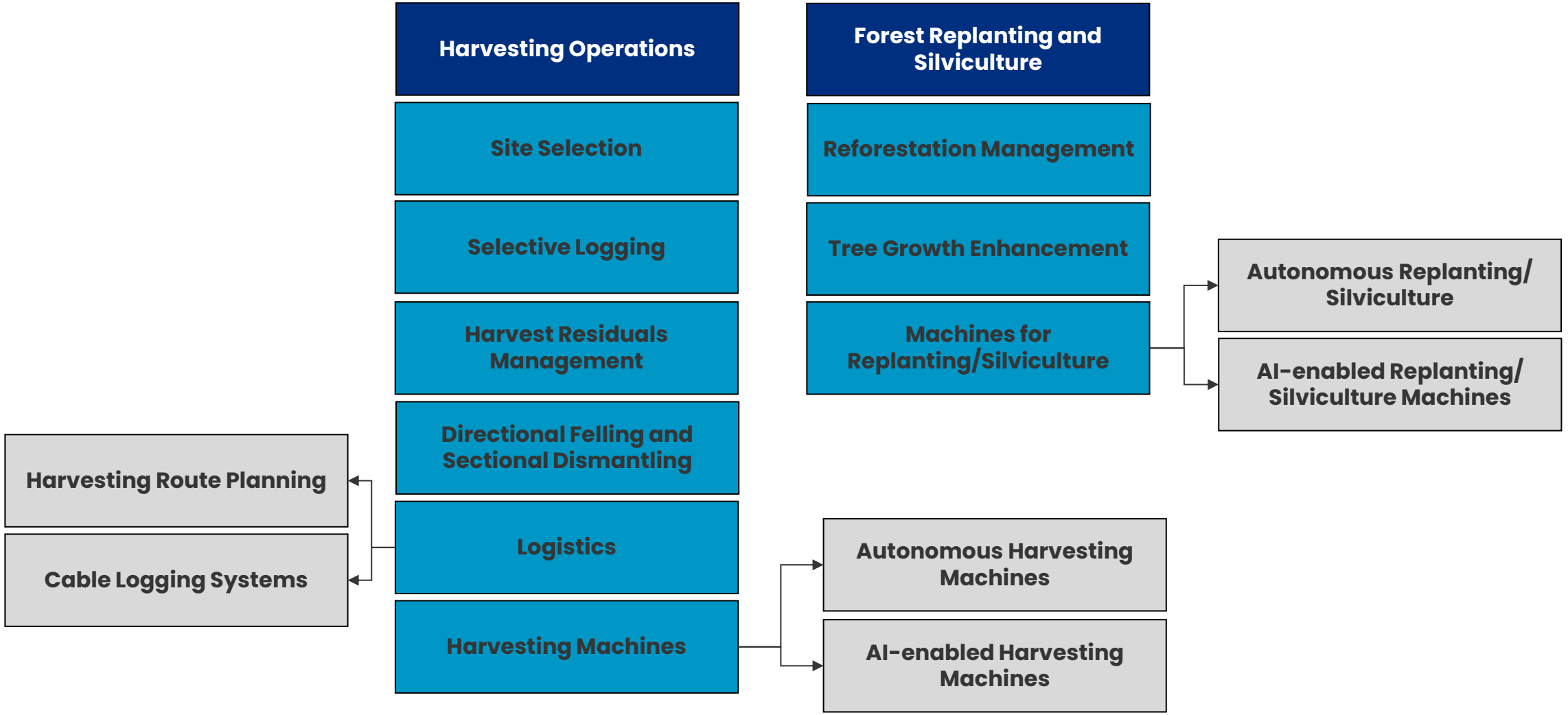
# Technology Taxonomy – Module A – Sustainable Forest Management (3/3)




Refer to **Appendix** for Taxonomy Definitions

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# Technology Taxonomy

## Module B – Sustainable Bioprocessing

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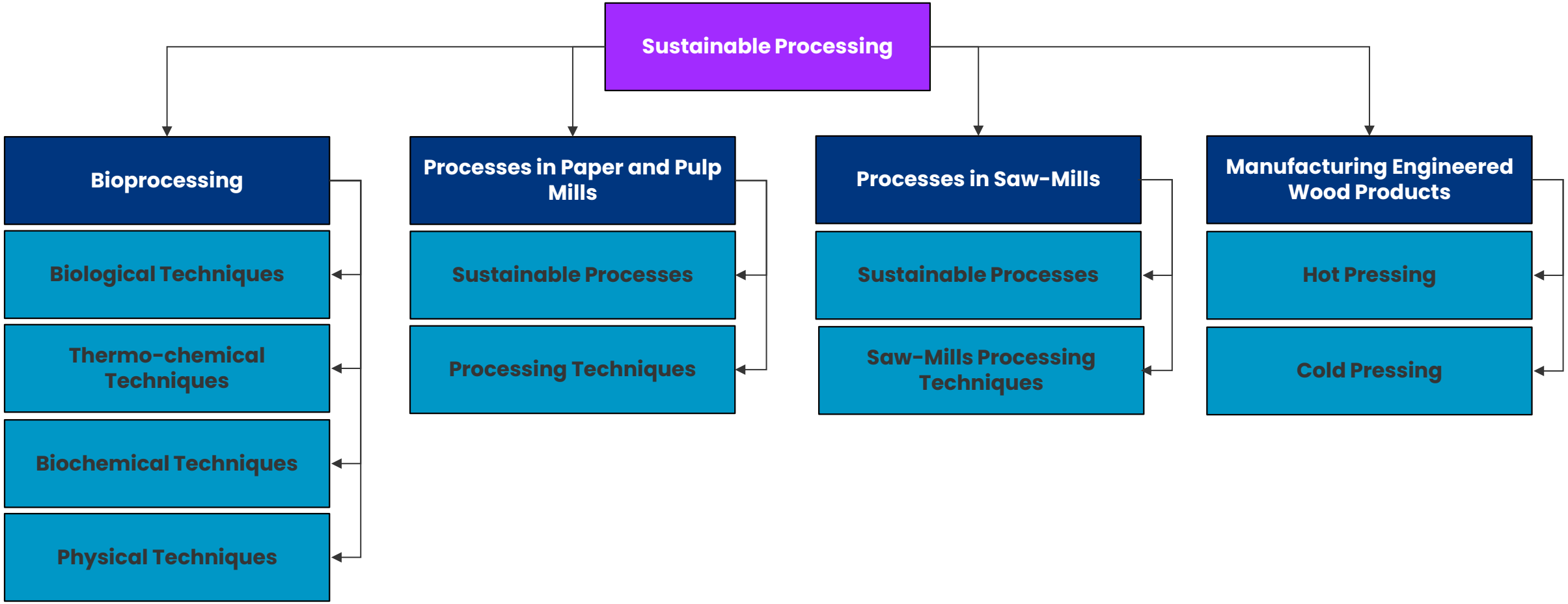
# Technology Taxonomy – Module B – Sustainable Bioprocessing (1/4)




Refer to **Appendix** for Taxonomy Definitions

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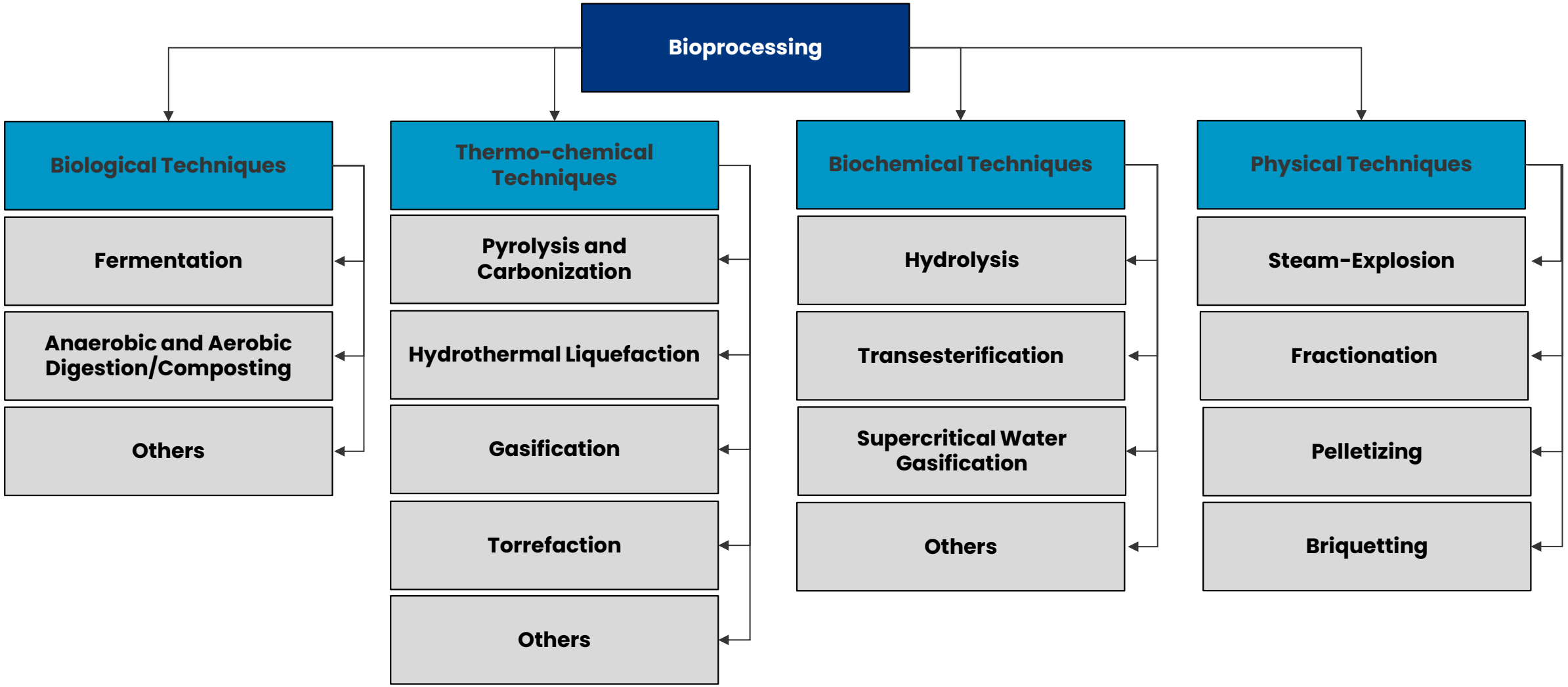
# Technology Taxonomy – Module B – Sustainable Bioprocessing (2/4)

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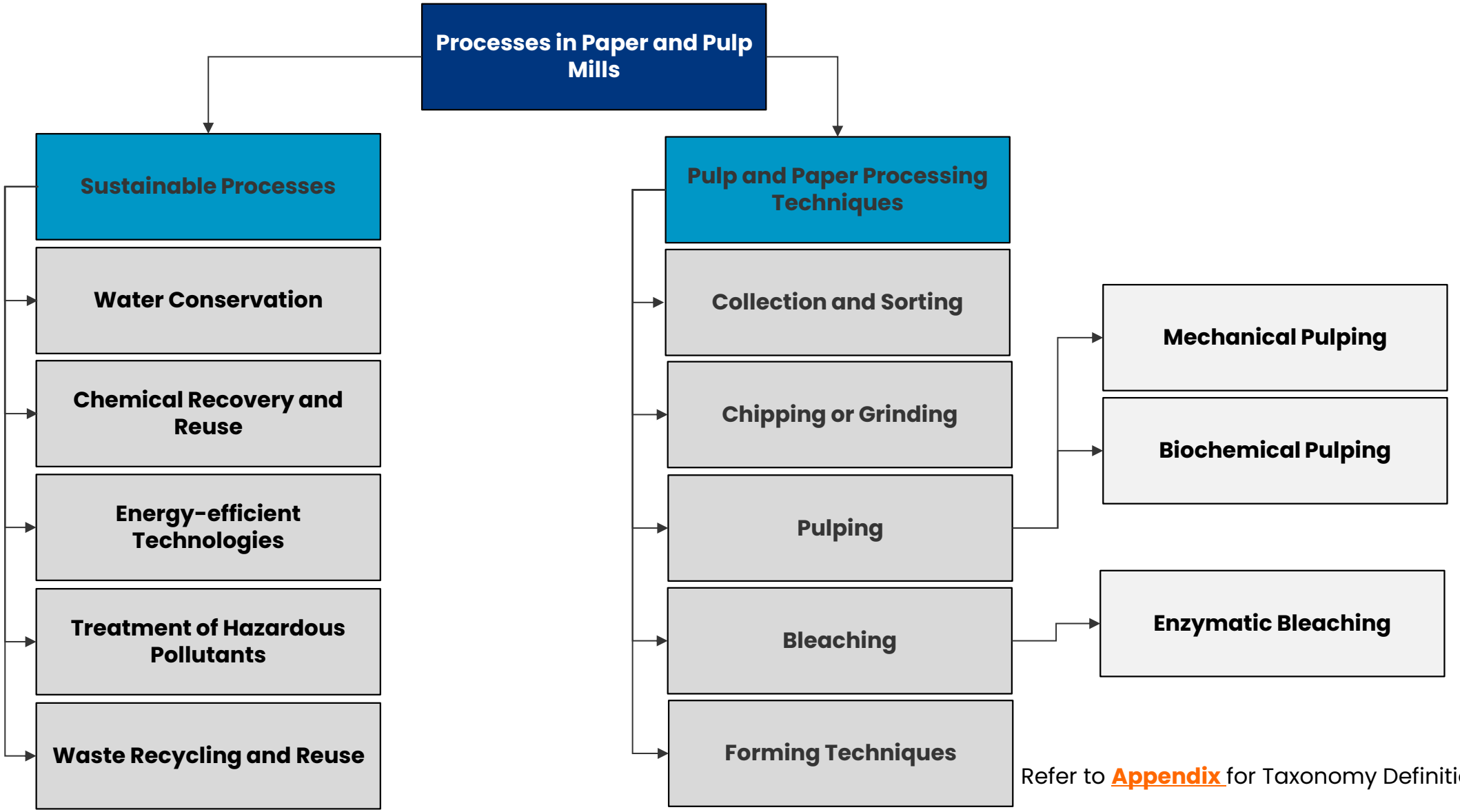
# Technology Taxonomy – Module B – Sustainable Bioprocessing (3/4)




Refer to **Appendix** for Taxonomy Definitions

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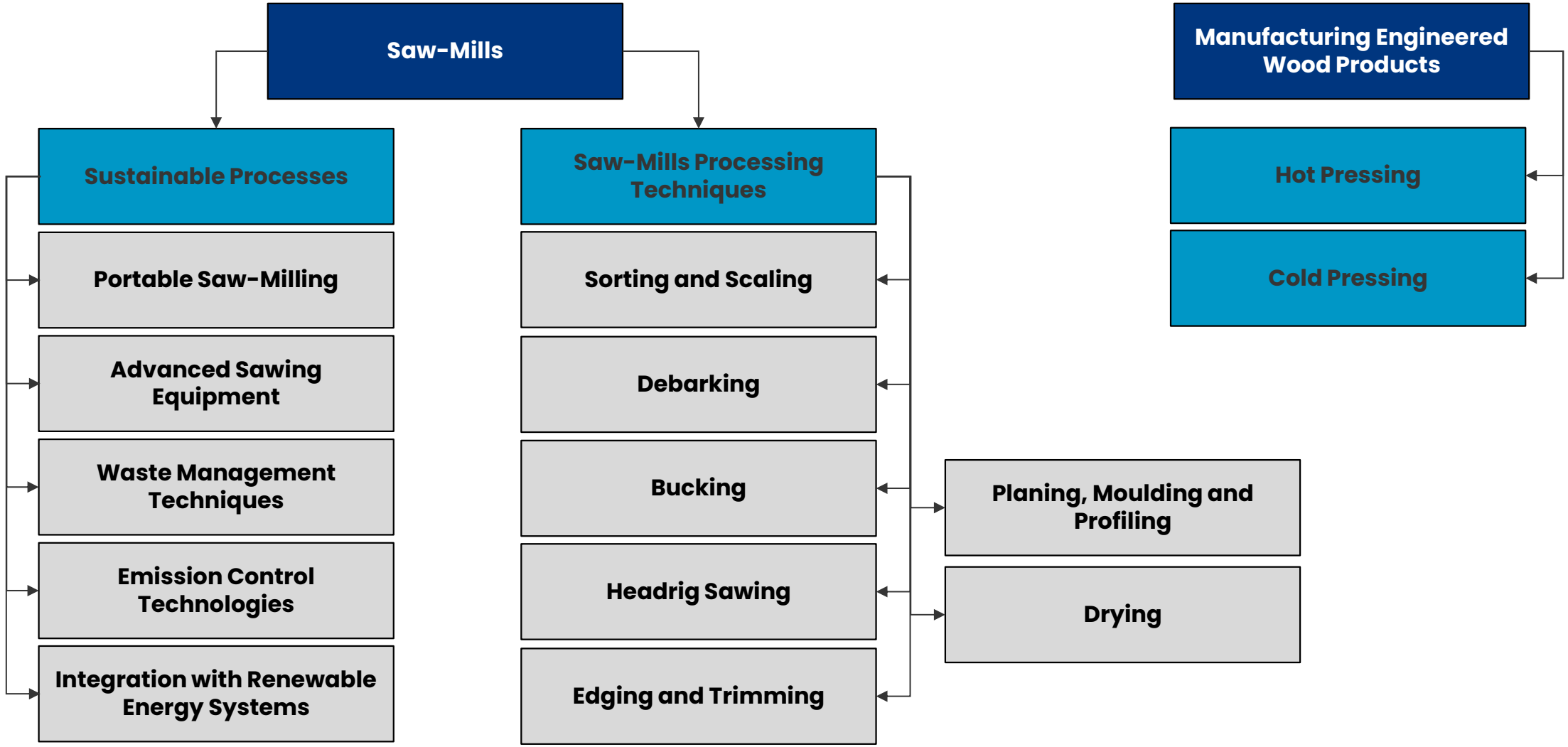
# Technology Taxonomy – Module B – Sustainable Bioprocessing (4/4)




Refer to **Appendix** for Taxonomy Definitions

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# Technology Taxonomy

## Module C – Value-added Products/ Materials/ Applications

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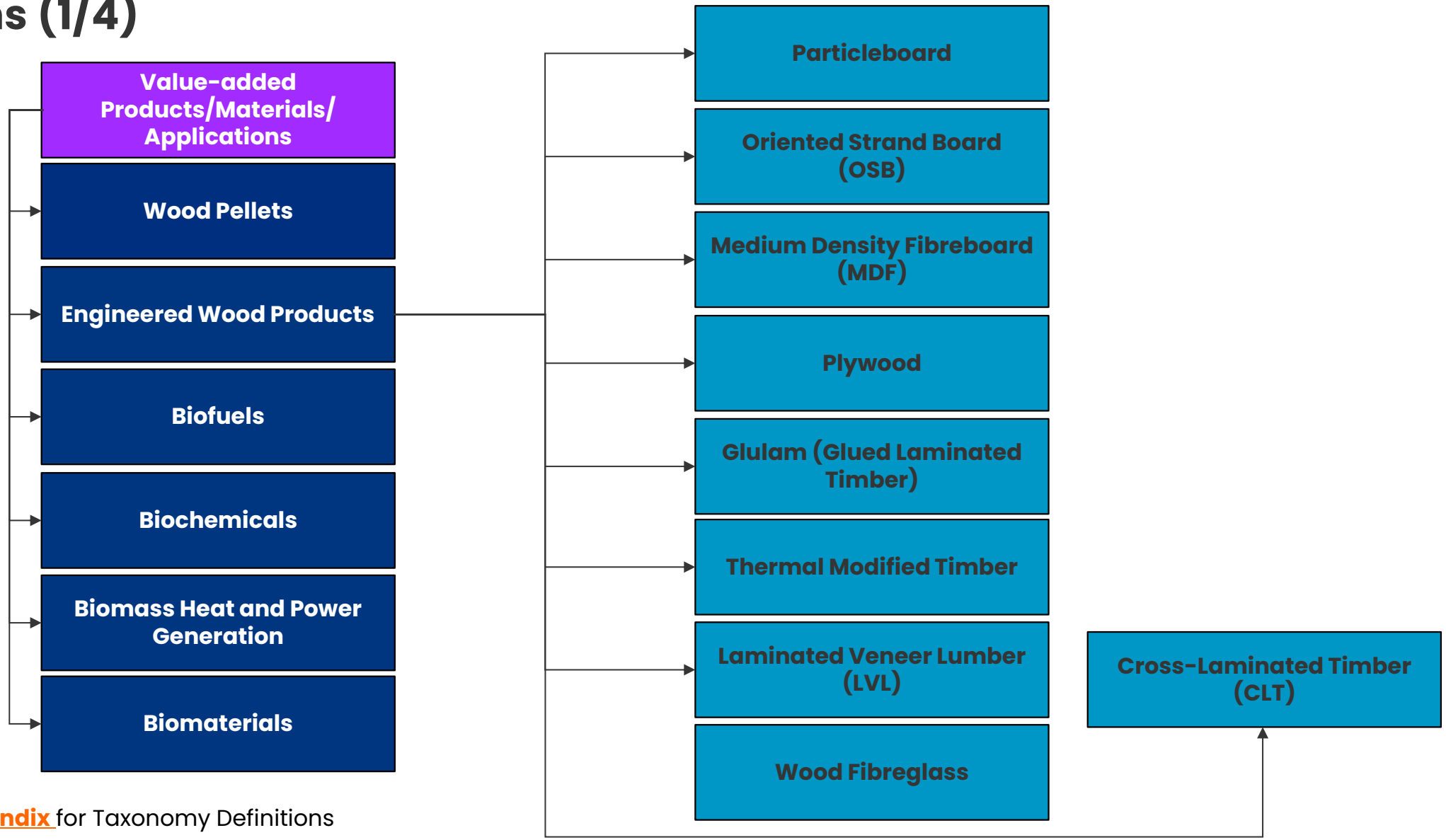
# Technology Taxonomy – Module C – Value-added Products/ Materials/ Applications (1/4)




Refer to **Appendix** for Taxonomy Definitions

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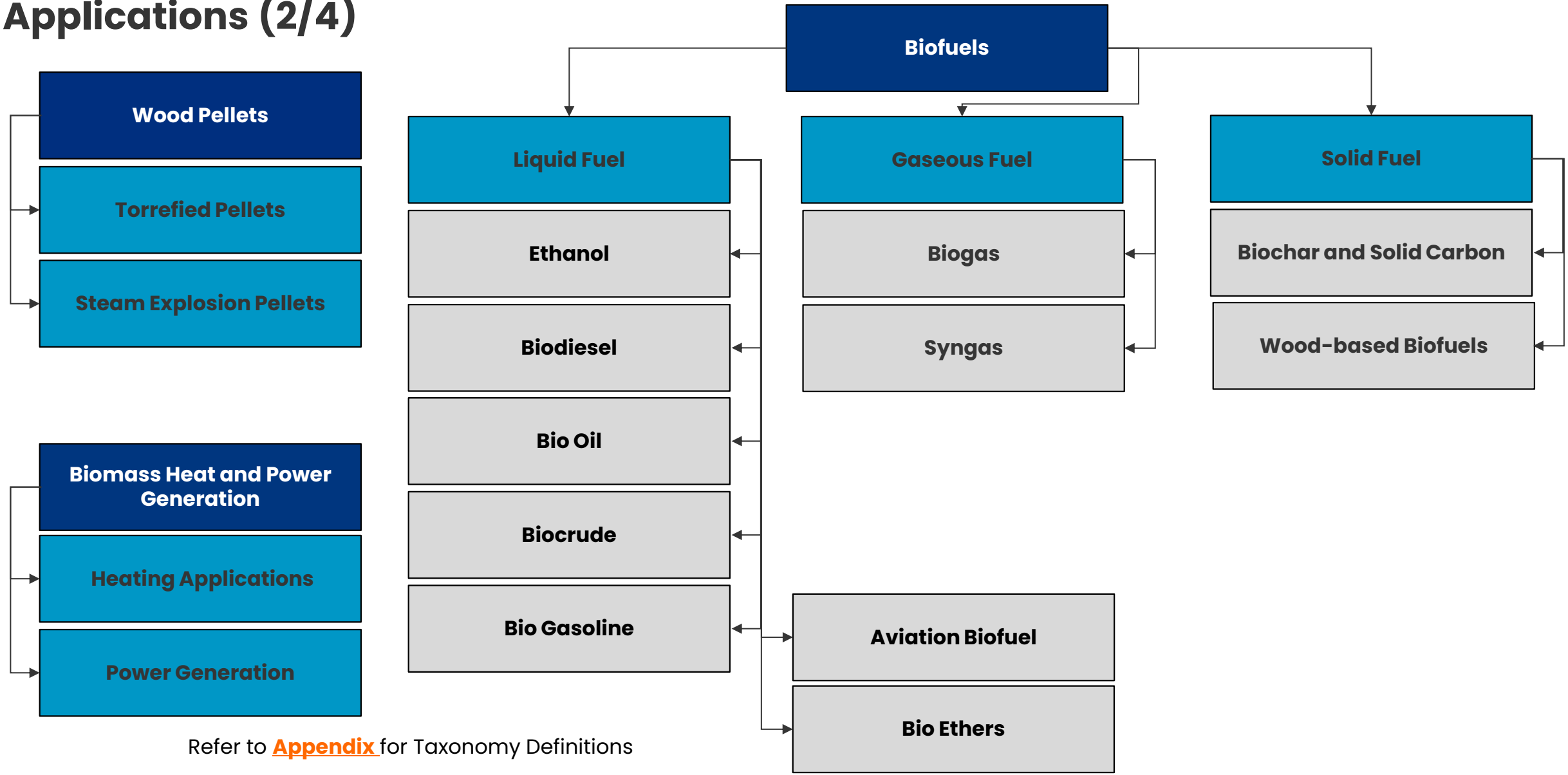
# Technology Taxonomy – Module C – Value-added Products/ Materials/ Applications (2/4)




Refer to **Appendix** for Taxonomy Definitions

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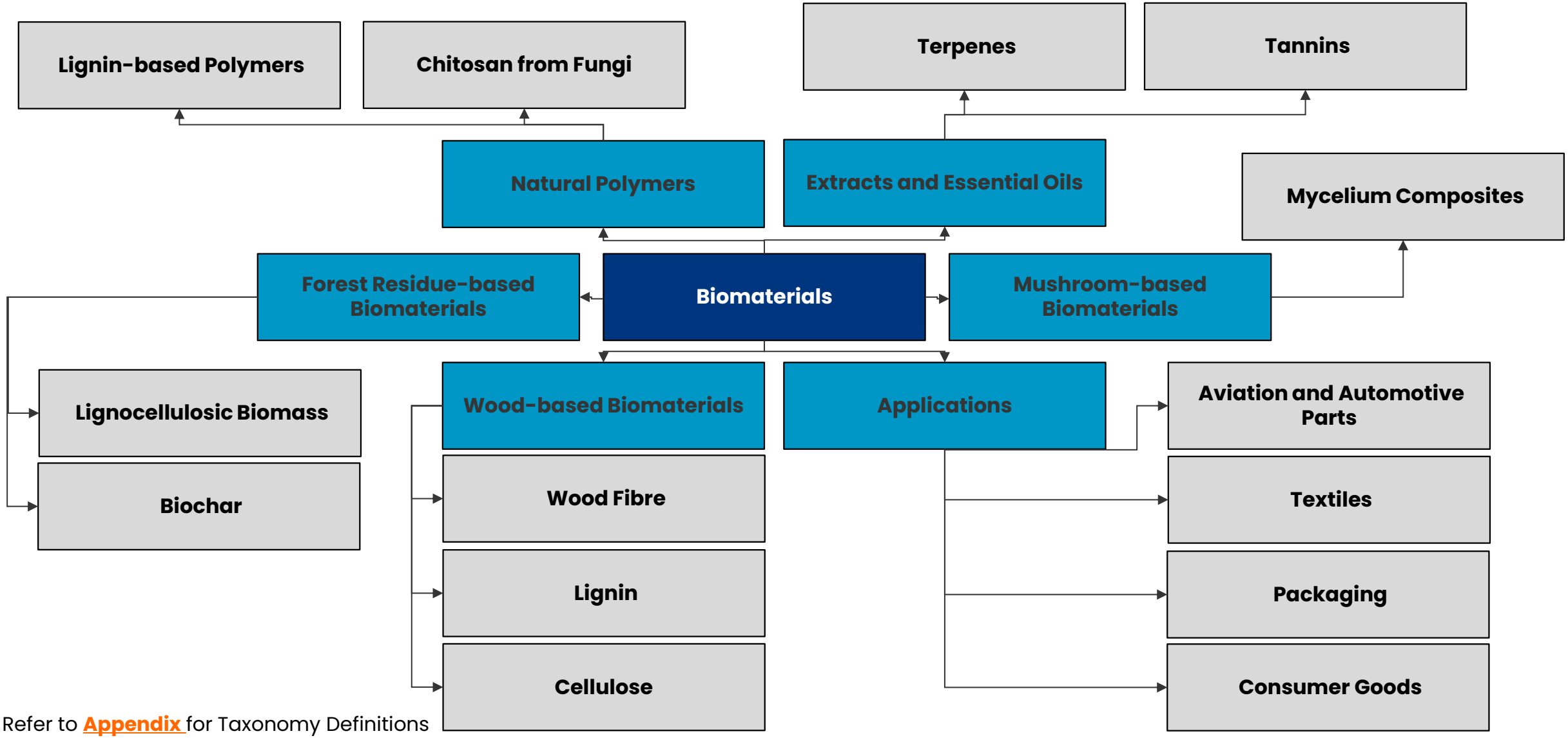
# Technology Taxonomy – Module C – Value-added Products/ Materials/ Applications (3/4)




Refer to **Appendix** for Taxonomy Definitions

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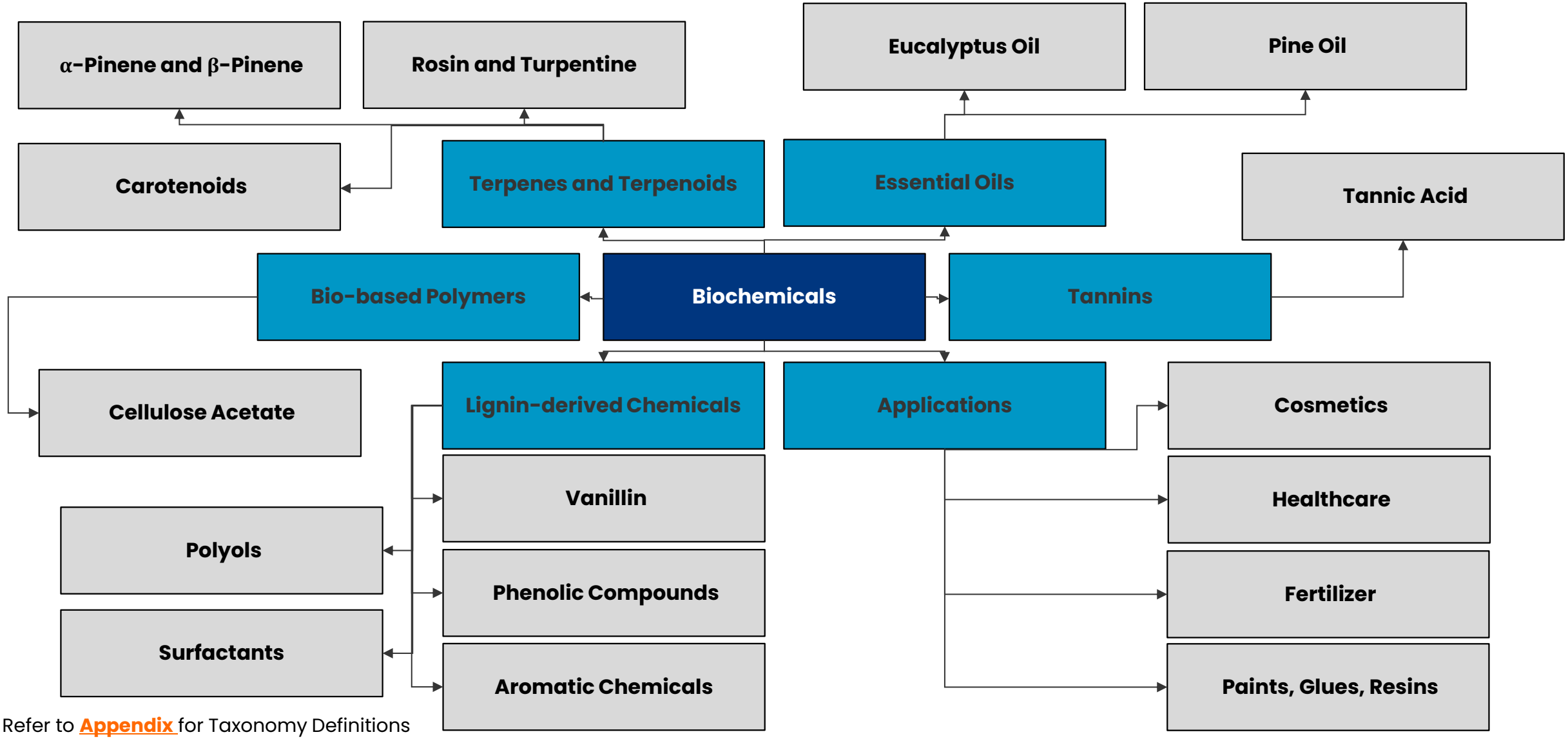
# Technology Taxonomy – Module C – Value-added Products/ Materials/ Applications (4/4)




Refer to **Appendix** for Taxonomy Definitions

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# Patent Insights

This section includes innovation trends, key assignees, geographical footprint, *etc.* Additionally, this section covers the technological progression trends, competitive positioning of different players in industry, litigation insights, *etc.* These insights help in developing R&D strategy, identifying emerging technologies, assessing market potential, and guiding IP protection and investment decisions.

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# Patent Insights

## Module A - Sustainable Forest Management

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# Executive Summary

# Module A— Sustainable Forest Management

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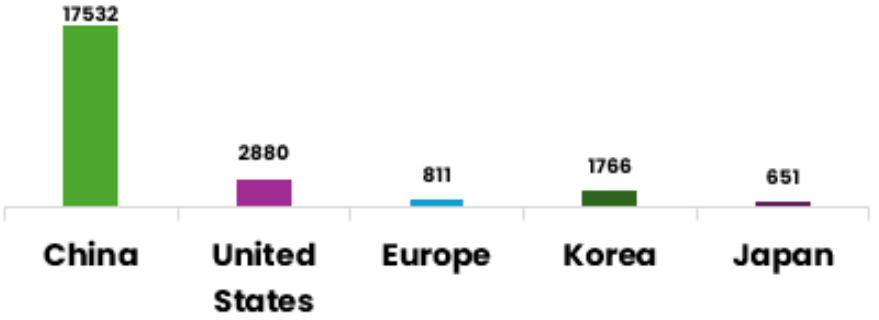
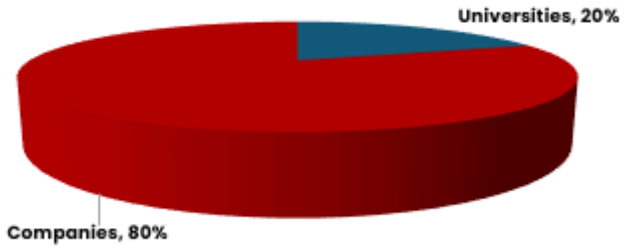
# Patent Insights - Executive Summary

## Key Jurisdictions

- China dominates the space with ~85% of the total patent assets.
- China is followed by the United States and Korea.
- **Canada stands at the 8th position with ~370 patent assets.**



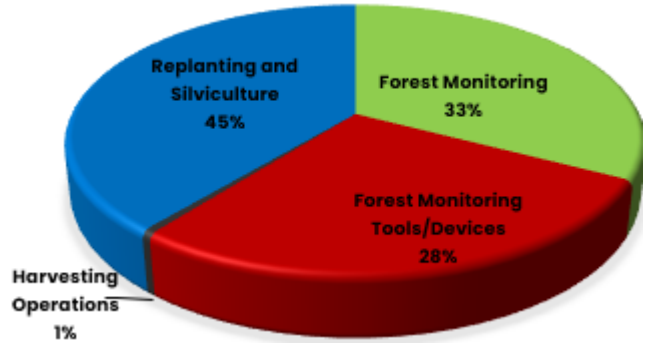




## Key Assignees

- As China holds the maximum patent portfolio, Chinese players dominate this technology area with ~80% share.
- ~20% (~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

# Module A— Sustainable Forest Management

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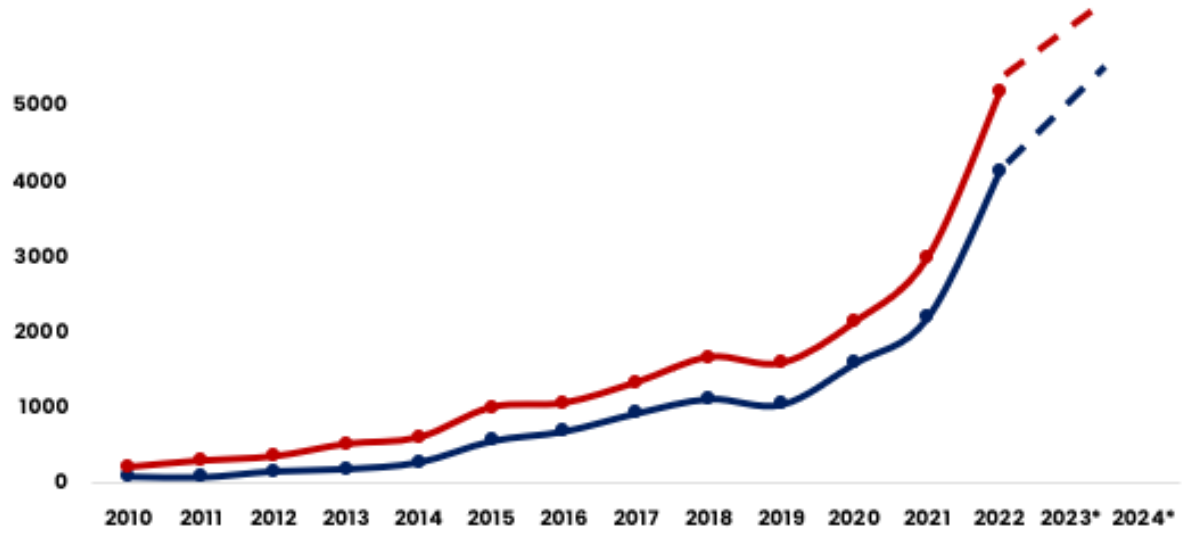
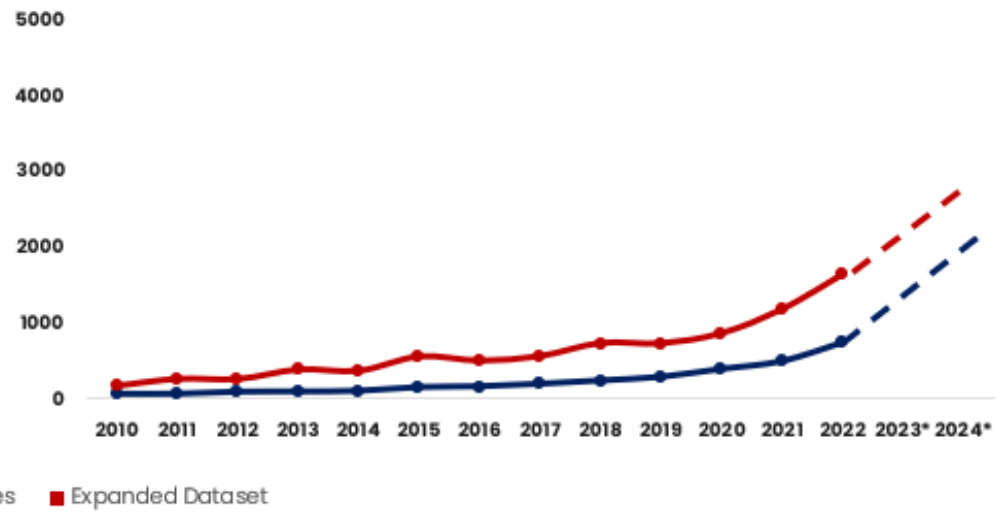
# Overall Filing Trend

**Global Filing Trend**




**Global Filing Trend excluding China**




Patent Families  Expanded Dataset

- The above graphs show a comparison between the global filing trend and the global filing trend excluding China, as China holds ~85% of the total patent assets.
- Including China, the total number of active patent families is ~20K, and the total active patent assets is ~27K.
- More than 90% of the total patent assets have a remaining life above 5 years.

***Notes:***

1. ** projected numbers have been shown for the years 2023-2024 as the numbers may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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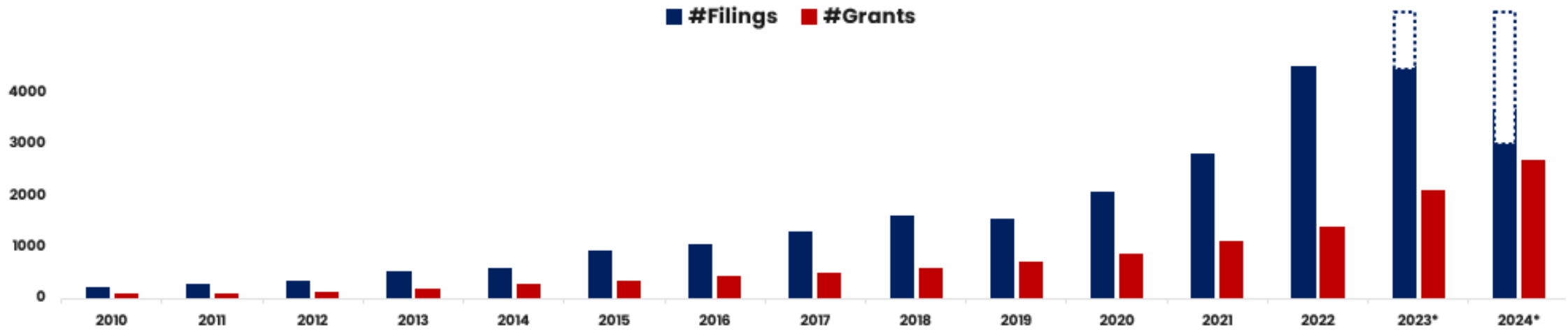
# Filing Trend vs. Grant Trend




*# Global active patent assets*

- The average number of filings per year for the last 5 years is ~2.5K, whereas the average number of grants per year for the last 5 years is ~1K (40% of average filings per year).
- **Canada has ~251 pending applications and ~119 granted patents in this domain.**
- Companies with the highest number of grants are Bayer AG (340) > Chinese Academy of Science (257) > Corteva Agriscience (172) > State Grid Corp. of China (149) > BASF SE (117).
- Jurisdictions with the highest number of grants are China (6,601) > United States (1,998) > Korea (1,091) > Europe (360). Brazil and Russia have around ~120 and ~171 granted patents, respectively.

***Notes:***

1. ** projected numbers have been shown for the years 2023-2024 as the numbers may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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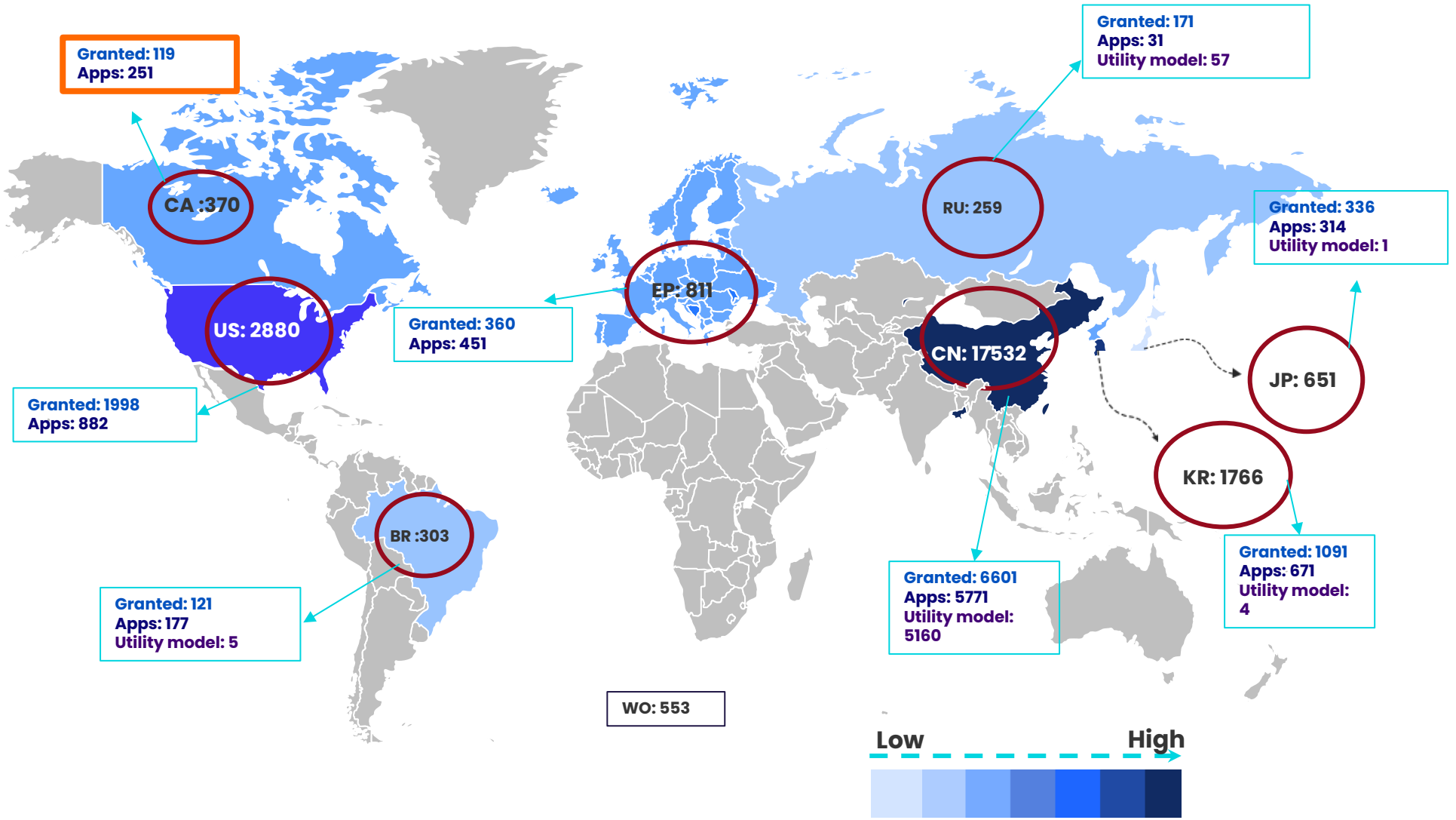
# Top Jurisdictions

| Top Countries by Patent Distribution | |
|---|---|
| **Country** | **Patent #** |
| China | 17,532 |
| United States | 2,880 |
| Korea | 1,766 |
| Europe | 811 |
| Japan | 651 |

| Top Countries by Forest Area | |
|---|---|
| **Country** | **Patent #** |
| Russia | 259 |
| Brazil | 303 |
| Canada | 370 |
| United States | 2,880 |
| China | 17,532 |

*# Global active patent assets*

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# Assignee-based Trends

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# Key Assignees in Top Countries by Patent Distribution

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

| CN | US | KR | EP | JP |
|---|---|---|---|---|
| State Grid Corp. of China (499) | Alphabet Inc. (210) | Korea Institute of Industrial Technology (241) | Bayer AG (43) | Bayer AG (17) |
| Chinese Academy of Science (408) | GE Aerospace (F/K/A General Electric Company) (133) | Bayer AG (18) | Dryad Networks GmbH (21) | BASF SE (15) |
| China Southern Power Grid Co. Ltd. (202) | AI Inc. (104) | BASF SE (13) | Sinochem Holding (Formerly Sinochem Corp) (20) | Sinochem Holding (Formerly Sinochem Corp) (10) |
| Univ Nanjing Forestry (197) | Strong Force VCN Portfolio 2019 LLC (80) | Corteva Agriscience (former Dow Agrosciences LLC) (5) | BASF SE (17) | GE Aerospace (F/K/A General Electric Company) (9) |
| Guangxi Zhuang Autonomous Region Inst (192) | Bayer AG (61) | Strong Force VCN Portfolio 2019 LLC (3) | Corteva Agriscience(former Dow Agrosciences LLC) (14) | Corteva Agriscience(former Dow Agrosciences LLC) (6) |
| Univ Beijing Forestry (189) | Indigo AG Inc. (42) | Sinochem Holding (Formerly Sinochem Corp) (2) | Indigo AG Inc. (10) | Strong Force VCN Portfolio 2019 LLC (4) |
| Inst Chem Ind Forest Prod Chinese Acad (186) | BASF SE (33) | GE Aerospace (F/K/A General Electric Company) (1) | Alphabet Inc. (5) | Alphabet Inc. (2) |
| Univ Northeast Forestry (99) | Corteva Agriscience(former Dow Agrosciences LLC) (22) | | Strong Force VCN Portfolio 2019 LLC (4) | |
| Sinochem Holding (Formerly Sinochem Corp) (99) | Sinochem Holding (Formerly Sinochem Corp) (20) | | | |
| Alphabet Inc. (35) | Dryad Networks GmbH (9) | | | |
| Bayer AG (32) | Univ Nanjing Forestry (2) | | | |
| GE Aerospace (F/K/A General Electric Company) (28) | Chinese Academy of Science (2) | | | |
| Dryad Networks GmbH (20) | Univ Northeast Forestry (1) | | | |
| BASF SE (16) | | | | |
| Corteva | | | | |

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

*# Global active patent assets*

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# Key Assignees in Top Countries by Forest Area

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

| RU | BR | CN | US | CA |
|---|---|---|---|---|
| GE Aerospace (F/K/A General Electric Company) (11) | BASF SE (29) | State Grid Corp. of China (499) | Korea Institute of Science and Technology (53) | Bayer AG (19) |
| Corteva Agriscience (Former Dow Agrosciences LLC) (9) | Sinochem Holding (Formerly Sinochem Corp.) (18) | Chinese Academy of Science (408) | Opusone Inc. (20) | Corteva Agriscience (Former Dow Agrosciences LLC) (12) |
| Bayer AG (3) | Bayer AG (18) | China Southern Power Grid Co. Ltd. (202) | Korea Institute of Industrial Technology (20) | Sinochem Holding (Formerly Sinochem Corp.) (11) |
| BASF SE (3) | Corteva Agriscience (Former Dow Agrosciences LLC) (15) | Univ Nanjing Forestry (197) | Korea Advanced Institute for Science and Technology (19) | Dryad Networks GmbH (10) |
| Sinochem Holding (Formerly Sinochem Corp.) (1) | Dryad Networks GmbH (7) | Guangxi Zhuang Autonomous Region Inst (192) | Nat Inst Forest Sci (18) | BASF SE (10) |
| | Indigo AG Inc. (6) | Univ Beijing Forestry (189) | Electronics and Telecommunications Research Institute (14) | Indigo AG Inc.(6) |
| | GE Aerospace (F/K/A General Electric Company) (6) | Inst Chem Ind Forest Prod Chinese Acad (186) | | Strong Force VCN Portfolio 2019 LLC (4) |
| | | Univ Northeast Forestry (99) | | |
| | | Sinochem Holding (Formerly Sinochem Corp) (99) | | |
| | | Alphabet Inc. (35) | | |
| | | Bayer AG (32) | | |
| | | GE Aerospace (F/K/A General Electric Company) (28) | | |

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

*# Global active patent assets*

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

The table below shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees based out of China have filed 16,618 patent families. The countries are chosen based on the highest patent counts (i.e., the top countries having the highest number of patent assets).

*# Global active patent assets*

| Global Patent Insights/Country | Chinese Assignees | US Assignees | Korean Assignees | European Assignees | Japanese Assignees |
|---|---|---|---|---|---|
| **Patent Families** | 16,618 | 1,023 | 2,855 | 158 | 173 |
| **Expanded Dataset** | 17,696 | 4,388 | 3,459 | 927 | 599 |
| **Granted Patents** | 6,839 | 2,468 | 817 | 476 | 311 |
| **Pending Applications** | 5,751 | 1,891 | 436 | 448 | 287 |
| **Utility Models** | 5,106 | 29 | 13 | 3 | 1 |
| **Key Assignees** | State Grid Corp. of China, Chinese Academy of Science, Univ Nanjing Forestry, China Southern Power Grid Co. Ltd. | Opusone Inc., Deere & Co., IBM, Qualcomm Incorporated, Boeing Co. | Public of Korea, Nat Inst Forest Science, Nat Disaster Management Res Inst | Dryad Networks GmbH, BASF SE, Bosch GmbH Robert, BASF Agro Trademarks GmbH | Sony Group Corp, Yanmar Holdings Co. Ltd., National Agriculture and Food Research Organization |
| **Key Jurisdictions** | CN, KR, US, WO | US, KR, IN, EP | KR, JP, US, IN | US, DE, EP, BR | JP, US, EP, CN |

*Notes:*

1. *INPADOC families are considered for this report - An INPADOC patent family encompasses all patent documents that share a priority relationship, either directly or indirectly (via a third document).*
2. *Expanded dataset is the sum of granted patents, pending applications and utility models.*

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# Technology Fragmentations

# Module A— Sustainable Forest Management

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# Technology Taxonomy Fragmentations

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

## Sustainable Forest Management

### Forest Monitoring

- Tree Health/Growth Assessment (2925 | 2229)
- Land Characteristics Assessment (1481 | 1176)
- Forest Inventory Management (1560| 1264)
- Wildfire (2958 | 2516)
- Storms (131| 50)
- Landslides/Earthquakes (573 | 176)
- Hydrological Events (231 | 187)
- Insect/Diseases Outbreaks (97 | 90)
- Real-time Natural Hazards Monitoring and Management (2214 | 1512)
- Predicting Natural Hazards (631 | 582)
- Carbon Footprint Tracking (1309 | 499)

### Forest Monitoring Tools/Devices

- GIS/Satellites (3419 | 2478)
- Drone/UAV (6219 | 4188)
- LiDAR (741 | 325)

### Forest Replanting and Silviculture

- Reforestation Management (7402 | 6776)
- Tree Growth Enhancement (4263| 2536)
- Autonomous Replanting/Silviculture (15 | 12)
- AI-enabled Replanting/Silviculture Machines (1 | 1)

### Harvesting Operations

- Site Selection (53 | 37)
- Selective Logging (70 | 36)
- Harvest Residuals Management (32 | 23)
- Directional Felling and Sectional Dismantling (6 | 4)
- Harvesting Route Planning (5 | 3)
- Cable Logging Systems (14 | 8)
- Autonomous Harvesting Machines (34 | 1)
- AI-enabled Harvesting Machines (1 | 1)

Link to Taxonomy Definitions

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

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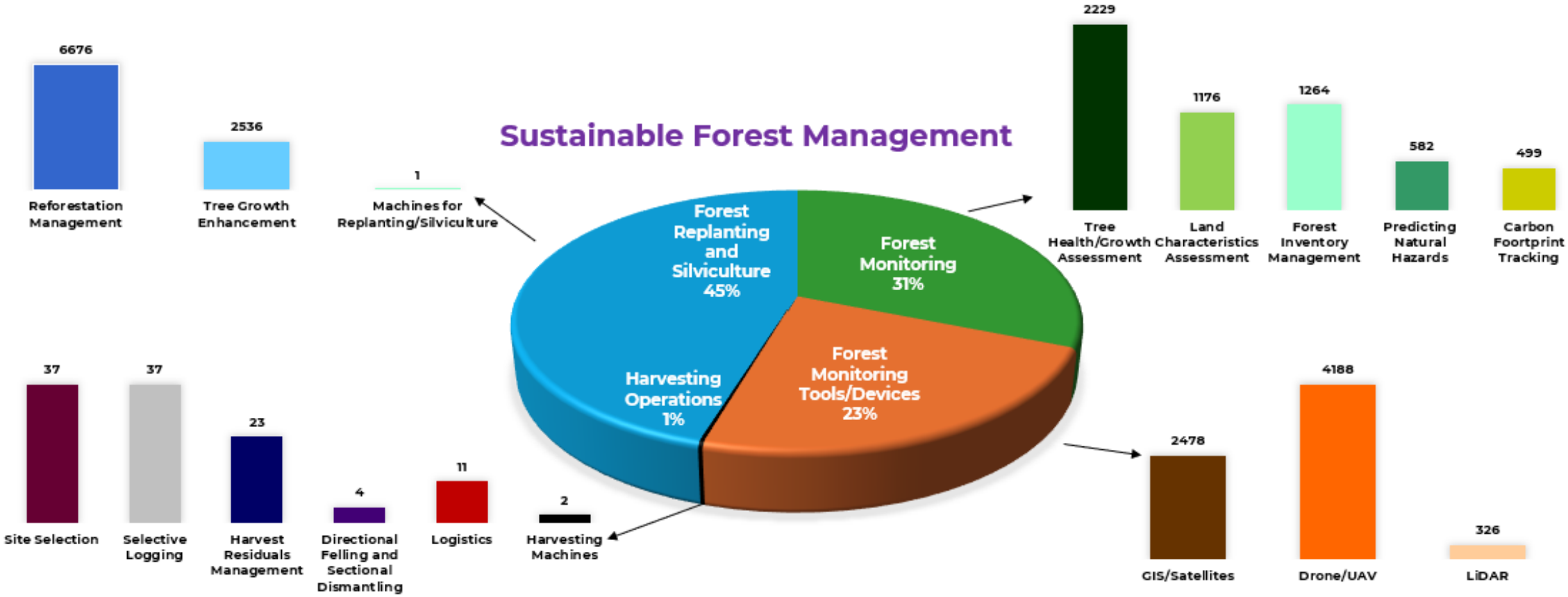
# Technology Fragmentations - Global




*# Global active patent families*

- The pie chart shows the patent distribution among tier-1 categories. Further, the corresponding column graphs show the patent distribution in respective tier-2 categories.
- Top countries for most of the tier-1 categories are China, Korea, and the United States; Brazil and Russia are the 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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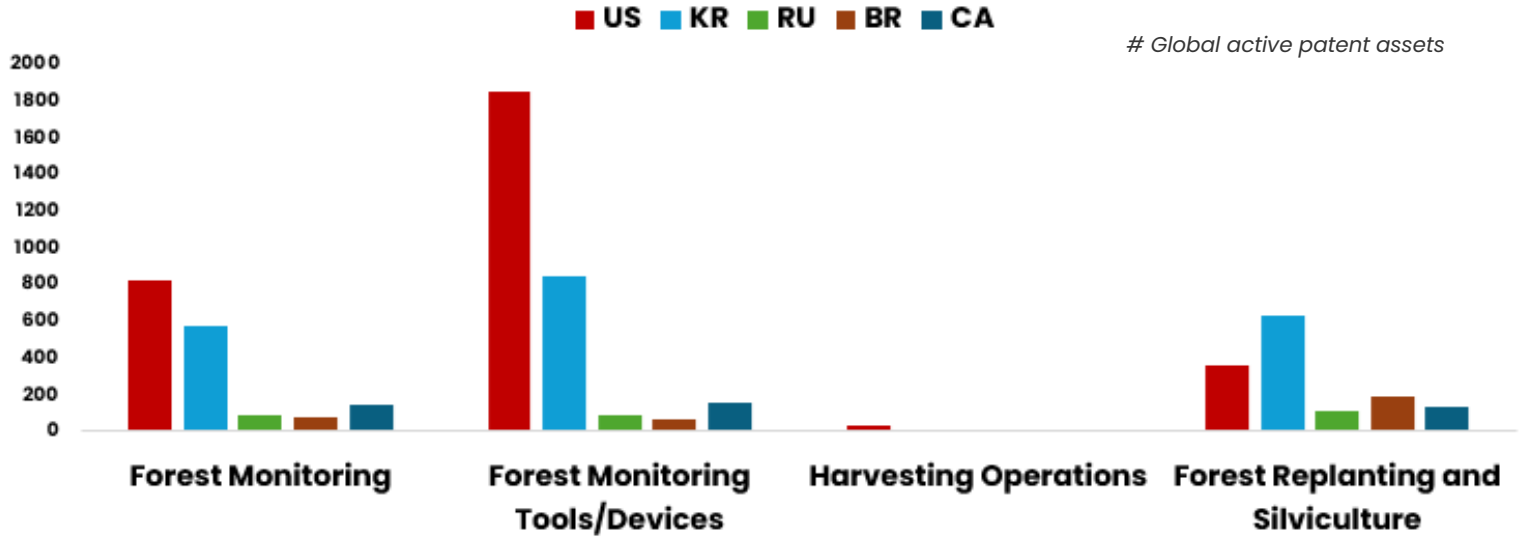
# Patent Distribution by Tier-1 Categories in Key Jurisdictions (Excluding China)




| Key Assignees | | | |
|---|---|---|---|
| **Forest Monitoring** | **Forest Monitoring Tools/Devices** | **Harvesting Operations** | **Forest Replanting And Silviculture** |
| Gen Electric (374) | Korea Institute of Industrial Technology (240) | Agri Technovation Pty Ltd. (10) | Bayer AG (425) |
| Dryad Networks GmbH (101) | Alphabet Inc. (230) | TMK Machinery Oy (6) | Corteva Agriscience( (257) |
| GE Global Sourcing LLC (73) | Strong Force VCN Portfolio (113) | Pisek Vitli KRPAN Doo (5) | BASF SE (216) |
| Gilead Sciences Inc. (59) | AI Inc. (104) | Dicosola M (5) | Sinochem Holding (142) |
| Transp IP Holdings LLC (55) | | Bridgestone Corp. (5) | Korea Institute of Industrial Technology (97) |

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# Patent Distribution in Key Countries (Excluding China)

*# Global active patent assets*

| Tier 1 Categories | Tier 2 categories | US | KR | EP | JP | CA |
|---|---|---|---|---|---|---|
| Forest Monitoring | Tree Health/Growth Assessment ** | 189 | 153 | 91 | 119 | 45 |
| | Land Characteristics Assessment | 98 | 67 | 31 | 41 | 27 |
| | Forest Inventory Management | 86 | 60 | 44 | 38 | 18 |
| | Natural Hazards Tracking | 81 | 250 | 24 | 21 | 1 |
| | Carbon Footprint Tracking ** | 152 | 92 | 30 | 33 | 29 |
| Forest Monitoring Tools/Devices | GIS/Satellites ** | 521 | 181 | 139 | 76 | 54 |
| | Drone/UAV | 268 | 397 | 50 | 53 | 2 |
| | LiDAR | 56 | 23 | 25 | 12 | 6 |
| Harvesting Operations | Site Selection * | 2 | 1 | 3 | 0 | 1 |
| | Selective Logging | 14 | 1 | 4 | 0 | 2 |
| | Harvest Residuals Management * | 4 | 0 | 2 | 0 | 0 |
| | Directional Felling and Sectional Dismantling * | 1 | 0 | 0 | 0 | 0 |
| | Logistics * | 2 | 0 | 1 | 1 | 0 |
| | Harvesting Machines * | 2 | 0 | 1 | 0 | 0 |
| Forest Replanting and Silviculture | Reforestation Management ** | 123 | 398 | 62 | 83 | 44 |
| | Tree Growth Enhancement ** | 232 | 229 | 151 | 103 | 84 |
| | Machines for Replanting/Silviculture * | 2 | 1 | 4 | 0 | 0 |

** These are the top areas where Canada has filed the maximum number of patents, reflecting significant focus and investment. **However, Canada is not among the top five jurisdictions globally in these areas.**

* Areas with a lower number of patent filings across all jurisdictions, indicating limited global interest. Canada is also not focusing on these areas. This presents a valuable opportunity to file patents in these niche domains.

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# Canadian Insights

# Module A— Sustainable Forest Management

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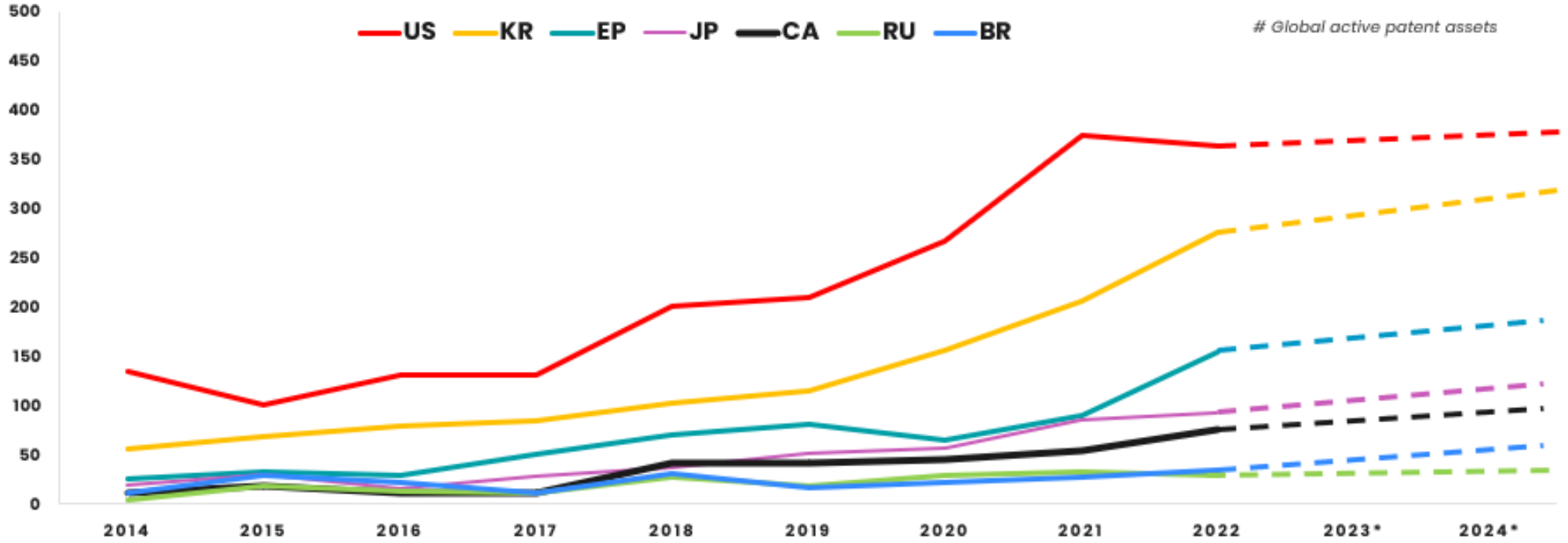
# Canadian vs. International Filings – Excluding China




- The above graph shows the patent filing trend in Canada along with other key jurisdictions (excluding China).
- Though Canada ranks third globally, with nearly 9% of the world's forests, it has significantly fewer filings as compared to other key jurisdictions, such as Korea and the United States. Over the past five years, the average number of filings in Canada has been approximately 37. In contrast, Korea and the United States have average filings of around 197 and 342, respectively, during the same period.
- The top three countries having maximum forest area are Russia, Brazil, and Canada. Russia has more filings, and Brazil has fewer filings as compared to Canada.

***Notes:***

1. ** projected numbers have been shown for years 2023-2024 as number may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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

The table below shows patent distribution by the assignee's country of origin, indicating where the assignees are based. For example, assignees based out of Russia have filed 180 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 | US Assignees | Chinese Assignees | Canadian Assignees |
|---|---|---|---|---|---|
| **Patent Families** | 180 | 56 | 1,023 | 16,618 | 41 |
| **Expanded Dataset** | 187 | 127 | 4,388 | 17,696 | 229 |
| **Granted Patents** | 112 | 64 | 2,468 | 6,839 | 143 |
| **Pending Applications** | 24 | 60 | 1,891 | 5,751 | 86 |
| **Utility Models** | 51 | 3 | 29 | 5,106 | 0 |
| **Key Assignees** | Petrozavodsk State University, Federal State Budgetary Educational, Samara State Agrarian University | Petroleo Brasileiro, Univ Sao Paulo, Univ Federal Rural Do Semi Arido, Univ Federal Rio Grande Norte | Opusone Inc., Deere & Co., IBM, Qualcomm Incorporated, Boeing Co. | State Grid Corp. of China, Chinese Academy of Science, Univ Nanjing Forestry, China Southern Power Grid Co. Ltd. | AI Inc., 0903608 BC Ltd., AL Inc., Terramera Inc., Carbonrun Carbon Dioxide Removal Ltd. |
| **Key Jurisdictions** | RU, AR, WO, US | BR, WO, ID, US | US, KR, IN, EP | CN, KR, US, WO | US, CA, EP |

*# Global active patent assets*

*Notes:*

1. *INPADOC families are considered for this report - An INPADOC patent family encompasses all patent documents that share a priority relationship, either directly or indirectly (via a third document).*
2. *Expanded dataset is the sum of granted patents, pending applications and utility models.*

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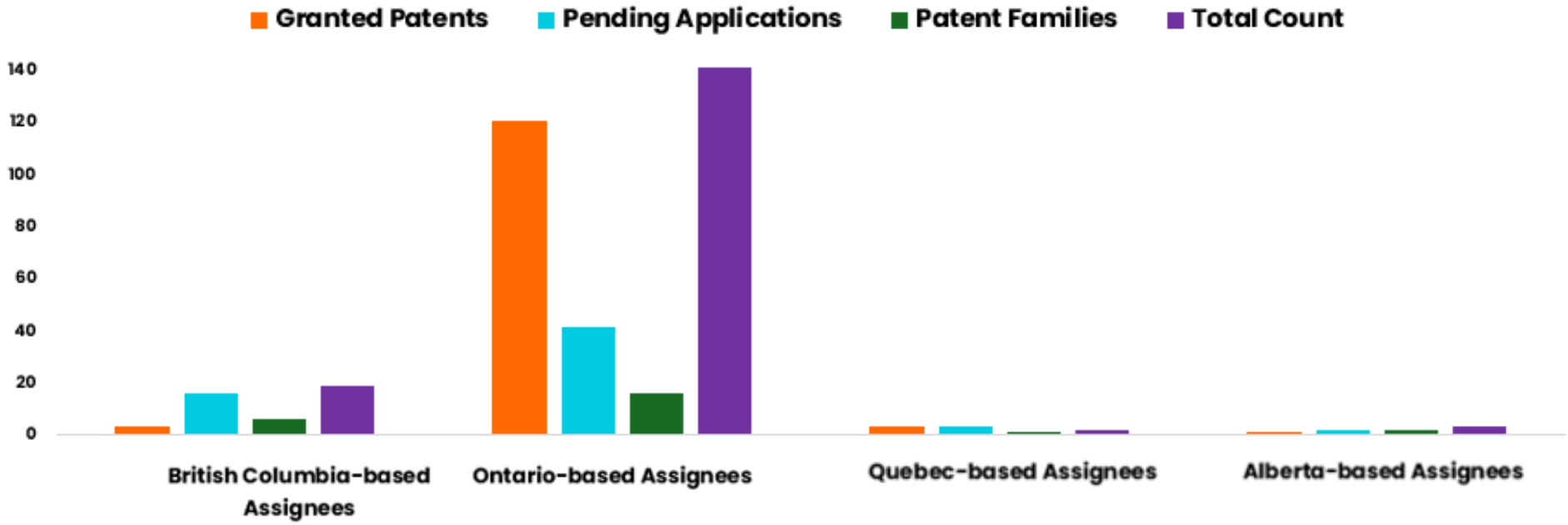
# BC vs Other Provinces




- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia, Alberta, Ontario and Quebec. Ontario-based companies seem to have filed more patents as compared to the other Canadian provinces. No significant patent filings were observed for Quebec- and Alberta-based companies/inventors.
- BC-based companies have maximum filings in GIS/Satellites, Drone/UAV, Real-time Natural Hazards Monitoring and Management, whereas Ontario-based companies have more filings in Forest Inventory Management, Drone/UAV, LiDAR.

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# Patent Insights

## Module B - Sustainable Bioprocessing
## &
## Module C - Value-added Products/ Materials/Applications

FORESIGHT

UnitedLex

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# Executive Summary

## Module B & Module C

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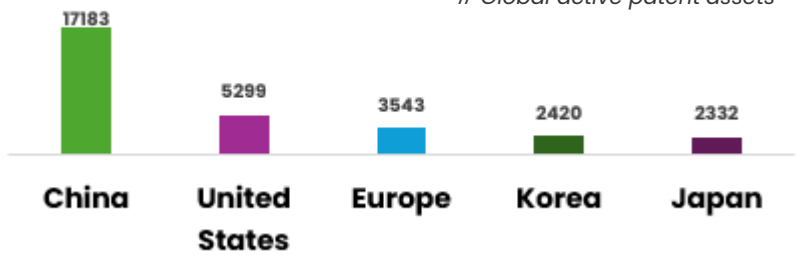
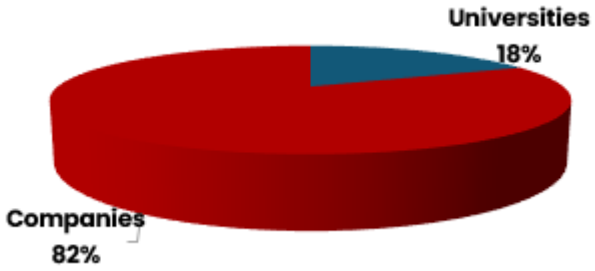
# Patent Insights - Executive Summary

## Key Jurisdictions

- China owns ~35% of the total patent assets.
- China is followed by the United States, Europe and Korea.
- **Canada stands at the 6th position with ~1730 patent assets.**

*# Global active patent assets*



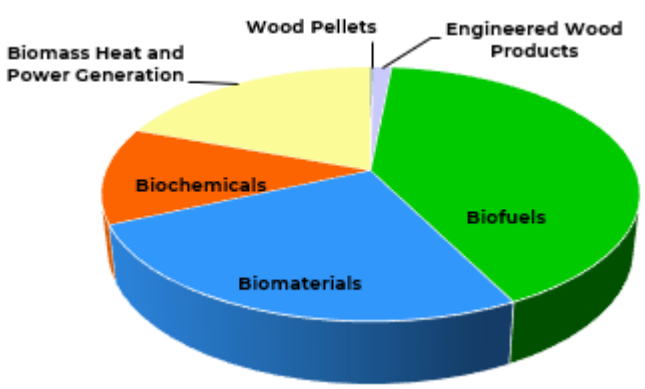

## Key Assignees

- As China holds the maximum patent portfolio, Chinese players dominate this technology area with ~80% share.
- ~18% (~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.

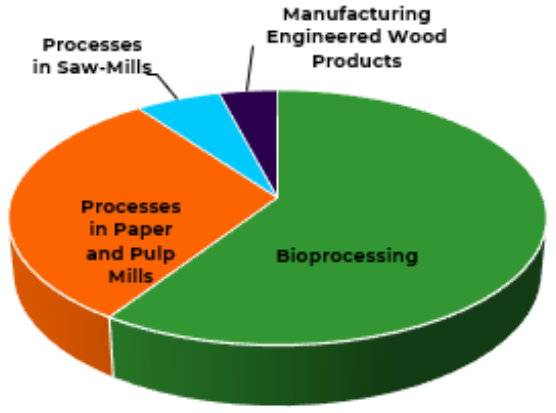
## Key Categories

- For Sustainable Bioprocessing, Bioprocessing category has the greatest share (~56%), followed by Processes in Paper and Pulp Mills (~26%). Comparatively fewer filings were observed in processes in Saw-Mills and Manufacturing Engineered Wood Products (i.e., ~1% of the patent share each).
- For Value-added Products/ Materials/Applications, 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%.

**Value-added Products/ Materials/Applications**




**Sustainable Bioprocessing**

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# Filing and Geography Trends

# Module B & Module C

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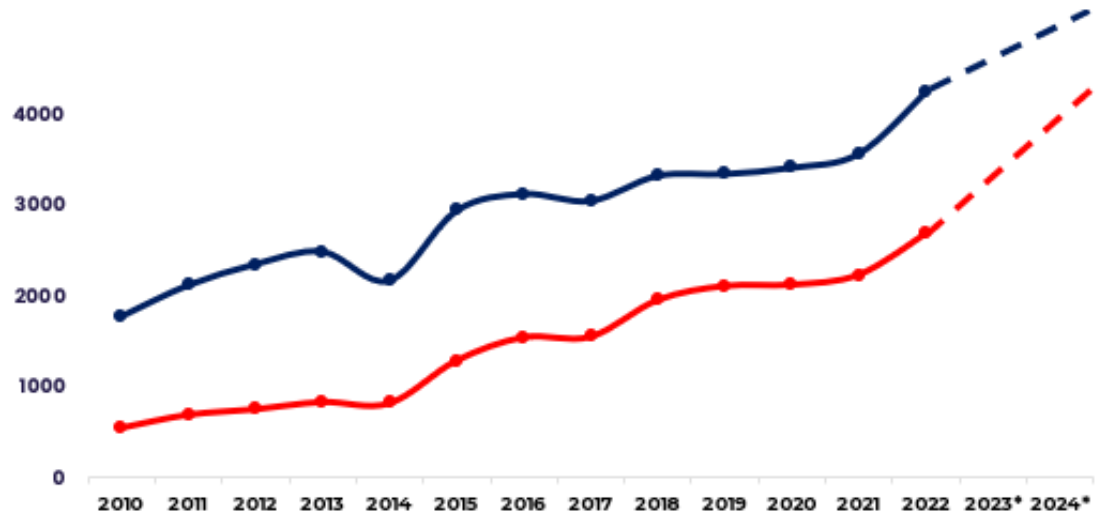
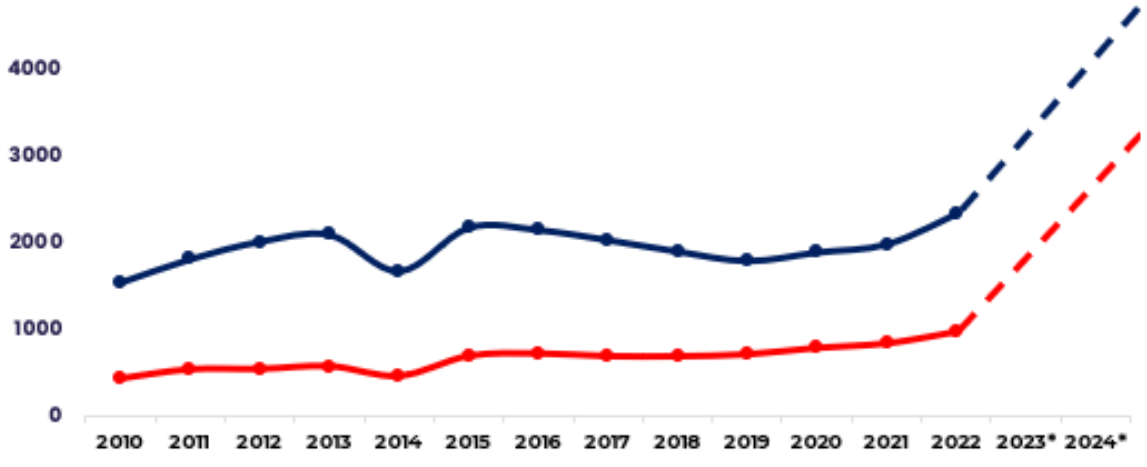
# Overall Filing Trend

**Global Filing Trend**




**Global Filing Trend excluding China**




Patent Families  Expanded Dataset

- The above graphs show a comparison between the global filing trend and the global filing trend excluding China.
- Including China, the total number of patent families is ~25K, and the total active patent assets are ~49K. Excluding China, the number of filings per year has reduced by ~60%.
- More than 90% of the total patent assets have a remaining life above 5 years.

***Notes:***

1. ** projected numbers have been shown for the years 2023-2024 as the number may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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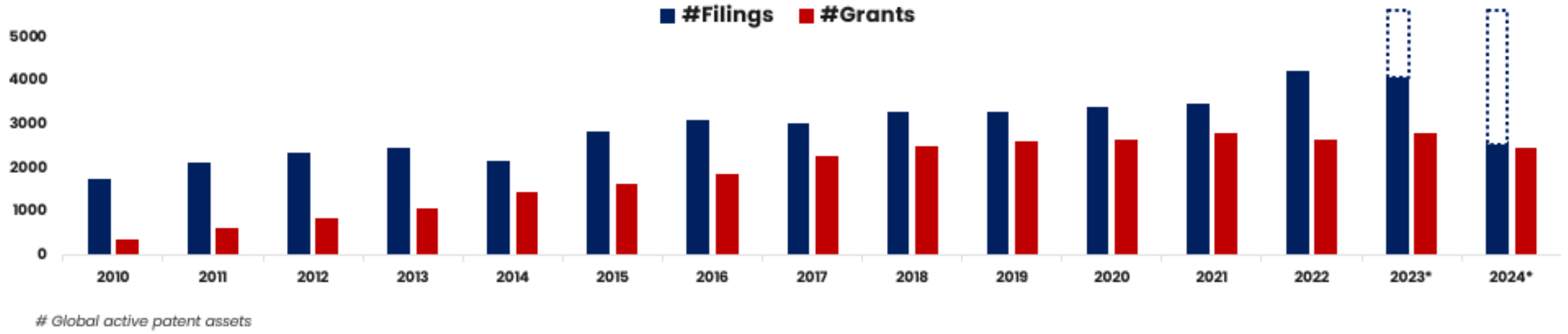
# Filing Trend vs. Grant Trend




*# Global active patent assets*

- The average number of filings per year for the last 5 years is ~3K, whereas the average number of grants per year for the last 5 years is ~2.5K (83% of average filings per year).
- **Canada has ~686 pending applications and ~1044 granted patents in this domain.**
- Companies with the highest number of grants are Ecolab Inc. (544) > Institut Francais Du Petrole (IFPEN) (421) > Kemira Oyj (319) > Chinese Academy of Science (301) > Andritz AG (271) > BASF SE (270), whereas companies with the highest filings are Xyleco Inc. (681) > Ecolab Inc. (652) > Regeneron Pharmaceuticals Inc. (650) > Institut Francais Du Petrole (IFPEN) (551).
- Jurisdictions with the highest number of grants are China (8,253) > United States (4,214) > Korea (1,818) > Japan (1,641). Brazil and Russia have around 300+ granted patents each.

***Notes***

1. ** projected numbers have been shown for the years 2023-2024 as the number may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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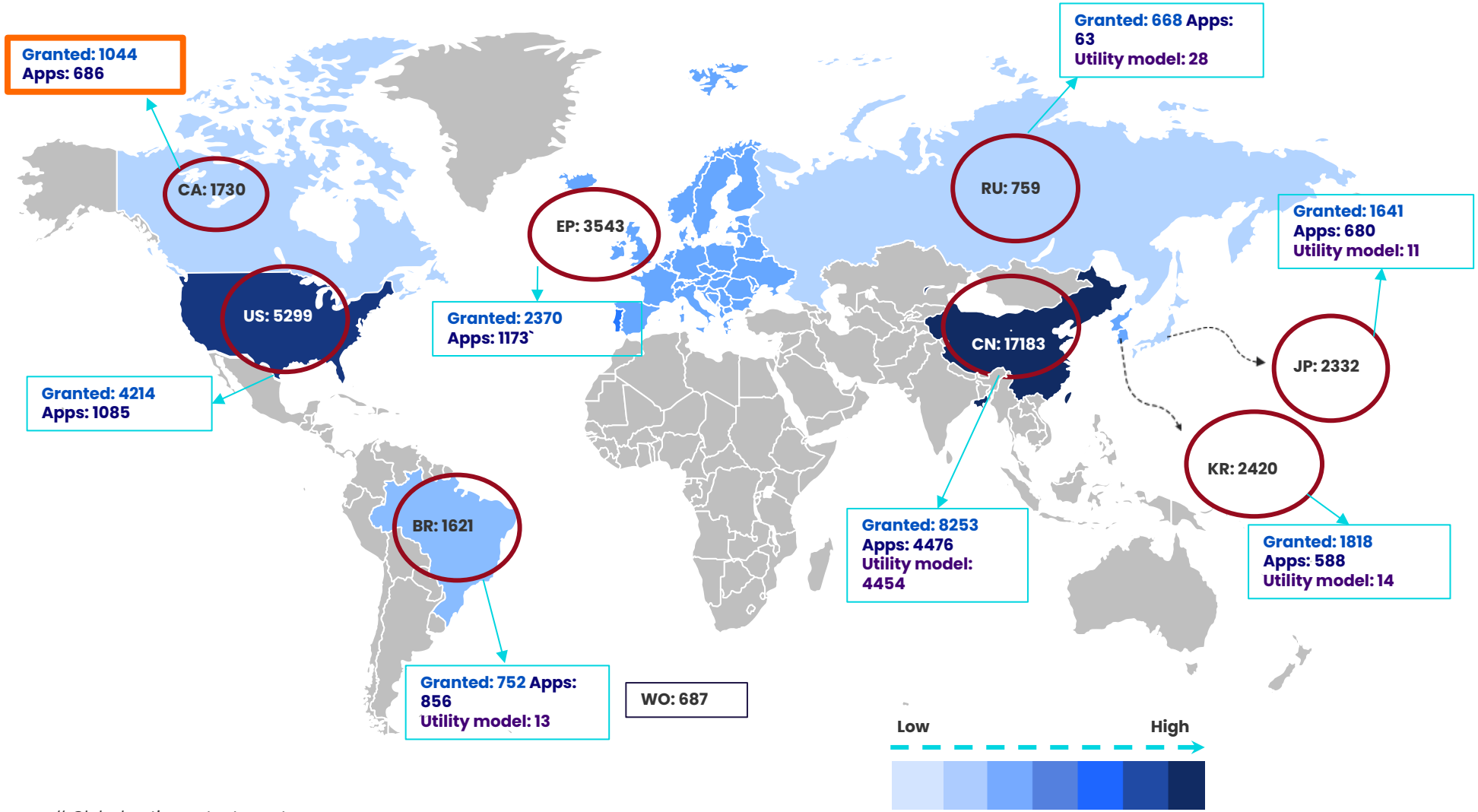
# Top Jurisdictions

| Top Countries by Patent Distribution | |
|---|---|
| **Country** | **Patent #** |
| China | 17,183 |
| United States | 5,299 |
| Europe | 3,543 |
| Korea | 2,420 |
| Japan | 2,332 |

| Top Countries by Forest Area | |
|---|---|
| **Country** | **Patent #** |
| Russia | 759 |
| Brazil | 1,621 |
| Canada | 1,730 |
| United States | 5,299 |
| China | 17,183 |




*# Global active patent assets*

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# Assignee-based Trends

# Module B & Module C

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# Key Assignees in Top Countries by Patent Distribution

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

| CN | US | EP | KR | JP |
|---|---|---|---|---|
| Chinese Academy of Science (375) | Ecolab Inc. (85) | Institut Francais Du Petrole (IFPEN) (64) | Korea Institute of Energy Research (Kier) (55) | Oji Holdings Corp. (55) |
| State Grid Corp. of China (271) | Bio-rad Laboratories Inc. (76) | Kemira Oyj (61) | Korea Institute of Science and Technology (50) | Nippon Paper Group Inc. (52) |
| China Petrochemical Corp. D/B/A Sinopec Group (F/K/A China Petroleum & Chemical Corp. Inc. D/B/A Sinopec) (221) | Carbon Technology Holdings LLC (71) | BASF SE (61) | Korea Institute of Industrial Technology (44) | Mitsubishi Heavy Industries Ltd. (52) |
| Univ Qilu Technology (132) | Graninvestimentos SA (67) | Ecolab Inc. (54) | Ecolab Inc. (37) | Ecolab Inc. (48) |
| South China University of Technology (128) | Institut Francais Du Petrole (IFPEN) (64) | Valmet Corporation (47) | Regeneron Pharmaceuticals Inc. (35) | Regeneron Pharmaceuticals Inc. (43) |
| Univ Nanjing Forestry (117) | Honeywell International Inc. (62) | Stora Enso AB (44) | Kemira Oyj (33) | Daio Paper Corp. (42) |
| Huazhong University of Science & Technology (113) | Xyleco Inc. (61) | Eastman Chemical Co. (42) | Xyleco Inc. (32) | Toppan Holdings Inc. (F/K/A Toppan Inc. Toppan Printing Co. Ltd.) (39) |
| Xian Thermal Power Res Inst Co. Ltd. (112) | Procter & Gamble Co. (58) | Upm-kymmene Corp. (41) | Lanzatech Global Inc. (F/K/A Lanzatech Nz) (31) | Dai Nippon Printing Co. Ltd. (37) |
| University Shandong (95) | Kemira Oyj (56) | Andritz AG (40) | Korea Research Institute of Chemical Technology - South Korea (30) | |
| Southeast University (91) | Eastman Chemical Co. (55) | Regeneron Pharmaceuticals Inc. (38) | | |
| Univ Kunming Sci & Technology (89) | | Lanzatech Global Inc. (F/K/A Lanzatech Nz) (36) | | |
| | | Carbon Technology Holdings LLC (36) | | |
| | | International Flavors & Fragrances Inc. (35) | | |
| | | Krono Holding AG (33) | | |

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

*# Global active patent assets*

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# Key Assignees in Top Countries by Forest Area

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

| RU | BR | CN | US | CA |
|---|---|---|---|---|
| Andritz AG (25) | Ecolab Inc. (47) | Chinese Academy of Science (375) | Ecolab Inc. (85) | Ecolab Inc. (52) |
| Kemira Oyj (24) | Andritz AG (35) | State Grid Corp. of China (271) | Bio-rad Laboratories Inc. (76) | Kemira Oyj (49) |
| Kvasenkov Oleg Ivanovich (23) | Kemira Oyj (32) | China Petrochemical Corp. D/B/A Sinopec Group (F/K/A China Petroleum & Chemical Corp. Inc. D/B/A Sinopec) (221) | Carbon Technology Holdings LLC (71) | Lanzatech Global Inc. (F/K/A Lanzatech Nz) (32) |
| Ecolab Inc. (23) | Spogen Biotech Inc. (30) | Univ Qilu Technology (132) | Graninvestimentos SA (67) | Institut Francais Du Petrole (Ifpen) (31) |
| Regeneron Pharmaceuticals Inc. (21) | Institut Francais Du Petrole (Ifpen) (28) | South China University of Technology (128) | Institut Francais Du Petrole (IFPEN) (64) | Norwood Ind Inc. (28) |
| Solenis LLC (13) | Stora Enso AB (25) | Univ Nanjing Forestry (117) | Honeywell International Inc. (62) | Anaergia Inc. (25) |
| Eni SpA (12) | BASF SE (25) | Huazhong University of Science & Technology (113) | Xyleco Inc. (61) | Stora Enso AB (23) |
| Albany International Corp. (12) | Valmet Corporation (23) | Xian Thermal Power Res Inst Co. Ltd. (112) | Procter & Gamble Co. (58) | Lallemand Inc. (23) |
| Xyleco Inc. (11) | Petroleo Brasileiro S.A. (23) | University Shandong (95) | Kemira Oyj (56) | Andritz AG (23) |
| Upm-kymmene Corp. (11) | Xyleco Inc. (21) | Southeast University (91) | Eastman Chemical Co. (55) | Solenis LLC (21) |
| Procter & Gamble Co. (11) | Graninvestimentos SA (21) | Univ Kunming Sci & Technology (89) | | Procter & Gamble Co. (21) |
| Krono Holding AG (11) | Solenis LLC (18) | | | |
| BASF SE (10) | Upm-kymmene Corp. (17) | | | |
| Renmatix Inc. (9) | Shell Plc (Royal Dutch/Shell Group Of Cos) (17) | | | |
| International Paper Co. (9) | Lanzatech Global Inc. (F/K/A Lanzatech Nz) (17) | | | |
| | Clariant AG (17) | | | |

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

*# Global active patent assets*

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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 based out of China have filed 13,723 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 | European Assignees | Japanese Assignees |
|---|---|---|---|---|---|
| **Patent Families** | 13,723 | 1,755 | 1,169 | 586 | 624 |
| **Expanded Dataset** | 14,482 | 8,050 | 1,441 | 2,046 | 1,657 |
| **Granted Patents** | 6,627 | 5,454 | 1,111 | 1,417 | 1,139 |
| **Pending Applications** | 3,634 | 2,586 | 327 | 590 | 513 |
| **Utility Models** | 4,221 | 10 | 3 | 39 | 5 |
| **Key Assignees** | Chinese Academy of Science (351)<br>State Grid Corp. of China (167)<br>Wuhan Kaidi Eng Technology Res Inst Co. (156)<br>Univ Qilu Technology (128) | Xyleco Inc. (488)<br>Nalco Co. (403)<br>Procter & Gamble (217)<br>Lanzatech Inc. (153)<br>Eastman Chem Co. (149) | C.J. Cheil Jedang Corp. (38)<br>LG Chemical Ltd. (34)<br>SK Innovation Co. Ltd. (27)<br>Korea Institute of Energy Research (27)<br>Korea Ind Tech Inst (22) | BASF SE (260)<br>Evonik Degussa GmbH (119)<br>Bosch GmbH Robert (89)<br>Fraunhofer Ges Forschung (55)<br>Clariant Produkte Deutschland GmbH (45) | Toray Industries (59)<br>Datalase Ltd. (33)<br>Jujo Paper Co. Ltd. (31)<br>Dainippon Ink & Chemicals (29)<br>Unicharm Corp. (28) |
| **Key Jurisdictions** | CN, US, WO, EP | US, EP, CA, CN | KR, US, CN, WO | EP, DE, CN, US | JP, CN, US, EP |

*Notes:*

1. *INPADOC families are considered for this report - An INPADOC patent family encompasses all patent documents that share a priority relationship, either directly or indirectly (via a third document).*
2. *Expanded dataset is the sum of granted patents, pending applications and utility models.*

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# Technology Fragmentations

## Module B & Module C

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# Technology Taxonomy Fragmentations (1/3)

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

## Sustainable Bioprocessing

### Bioprocessing

#### Biological Techniques

- Fermentation (7534 | 3199)
- Anaerobic and Aerobic Digestion/Composting (1192 | 1169)

#### Thermo-chemical Techniques

- Pyrolysis and Carbonization (7609 | 4950)
- Hydrothermal Liquefaction (216 | 123)
- Gasification (3952 | 3834)
- Torrefaction (791 | 291)

#### Biochemical Techniques

- Hydrolysis (2936 | 1073)
- Transesterification (581 | 286)
- Supercritical Water Gasification (14 | 14)

#### Physical Techniques

- Fractionation (648 | 163)
- Steam-Explosion (467 | 99)
- Pelletizing (81 | 55)
- Briquetting (267 | 147)

#### Manufacturing Engineered Wood Products

- Hot Pressing (1884 | 1006)
- Cold Pressing (326 | 182)

### Processes in Paper and Pulp Mills

#### Sustainable processes

- Water Conservation (3043 | 1267)
- Chemical Recovery and Reuse (403 | 83)
- Energy-efficient Technologies (1103 | 539)
- Treatment of Hazardous Pollutants (1089 | 455)
- Waste Recycling and Reuse (1314 | 491)

#### Pulp and Paper Processing Techniques

- Collection and Sorting (457 | 167)
- Chipping or Grinding (1758 | 980)
- Mechanical Pulping (1974 | 687)
- Biochemical Pulping (1113 | 575)
- Enzymatic Bleaching (935 | 228)
- Forming Techniques (5339 | 2378)

### Processes in Saw-Mills

#### Sustainable processes

- Portable Saw-Milling (400 | 108)
- Advanced Sawing Equipment (1223 | 231)
- Waste Management Techniques (44 | 24)
- Emission Control Technologies (80 | 13)
- Integration with Renewable Energy Systems (185 | 50)

#### Saw-Mills Processing Techniques

- Sorting and Scaling (556 | 249)
- Debarking (76 | 36)
- Bucking (550 | 264)
- Headrig Sawing (19 | 18)
- Edging and Trimming (296 | 153)
- Planing, Moulding and Profiling (256 | 65)
- Drying (111 | 43)

Link to Taxonomy Definitions

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

# Technology Taxonomy Fragmentations (2/3)

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

## Value-added Products/Materials/Applications

### Engineered Wood Products

- Particleboard (109 | 33)
- Oriented Strand Board (OSB) (124 | 28)
- Glulam (Glued Laminated Timber) (3 | 3)
- Thermal Modified Timber (0 | 0)
- Laminated Veneer Lumber (LVL) (12 | 6)
- Medium Density Fibreboard (MDF) (44 | 17)
- Plywood (286 | 67)
- Wood Fibreglass (28 | 8)
- Cross-Laminated Timber (CLT) (12 | 3)

### Biofuels

#### Liquid Fuel

- Ethanol (1798 | 535)
- Biodiesel (769 | 343)
- Bio oil (611 | 308)
- Biocrude (165 | 40)
- Bio Gasoline (9 |6)
- Bio Ethers (1 | 1)
- Aviation Biofuel (25 | 14)

#### Gaseous Fuel

- Biogas (2334 | 1071)
- Syngas (3636| 1338)

#### Solid Fuel

- Biochar and Solid Carbon (1218 | 668)
- Wood-based Biofuels (490 | 182)

### Biomaterials

#### Wood-based Biomaterials

- Wood Fibre (189 | 53)
- Lignin (2049 | 666)
- Cellulose (3739 | 968)

#### Forest Residue-based Biomaterials

- Lignocellulosic Biomass (1582 | 280)
- Biochar (418 | 139)

#### Natural Polymers

- Lignin-based Polymers (42 | 27)
- Chitosan from Fungi (46 | 40)

#### Extracts and Essential Oils

- Terpenes (260 | 71)
- Tannins (73 | 29)

#### Mushroom-based Biomaterials

- Mycelium Composites (72 | 46)

#### Applications

- Aviation and Automotive Parts (99 | 33)
- Textiles (1716 | 236)
- Packaging (882 | 229)
- Consumer Goods (153 | 28)

### Wood Pellets

- Torrified Pellets (89 | 11)
- Steam Explosion Pellets (4 | 2)

### Biomass Heat and Power Generation

- Heating Applications (2527 | 1528)
- Power Generation (2089 | 1532)

Link to Taxonomy Definitions

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

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# Technology Taxonomy Fragmentations (3/3)

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

## Value-added Products/Materials/Applications

### Biochemicals

#### Lignin-derived Chemicals

- Vanillin (73 | 37)
- Phenolic Compounds (792 | 332)
- Aromatic Chemicals (534 | 148)
- Polyols (780| 196)
- Surfactants (394 | 72)

#### Terpenes and Terpenoids Biomaterials

- α-Pinene and β-Pinene (2 | 2)
- Rosin and Turpentine (69 | 41)
- Carotenoids (29 | 2)

#### Essential Oils

- Eucalyptus Oil (9 | 7)
- Pine Oil (4 | 4)

#### Tannins

- Tannic Acid (34 | 18)

#### Applications

- Cosmetics (243 | 42)
- Healthcare (198 | 17)
- Fertilizer (503 | 161)
- Paints, Glues, Resins (1527 | 530)

#### Bio-based Polymers Biomaterials

- Cellulose Acetate (101 | 16)

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

Link to Taxonomy Definitions

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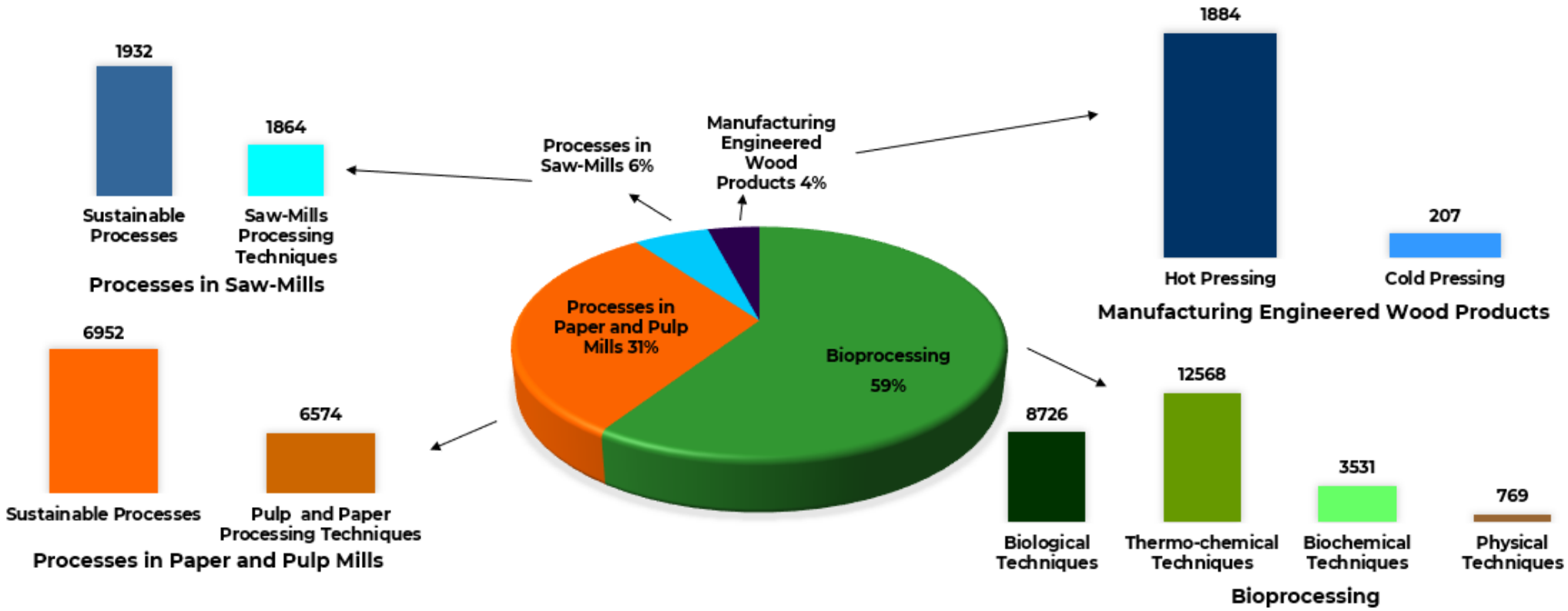
# Technology Fragmentations - Global - Sustainable Bioprocessing




*# Global patent families*

- The pie chart shows the patent distribution among tier-1 categories. Further, the corresponding column graphs show the 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 the United States, Europe, Korea, and Japan.
- Tier-2 categories – Biological techniques and Thermo-chemical techniques in Bioprocessing have greater filings as compared to others.

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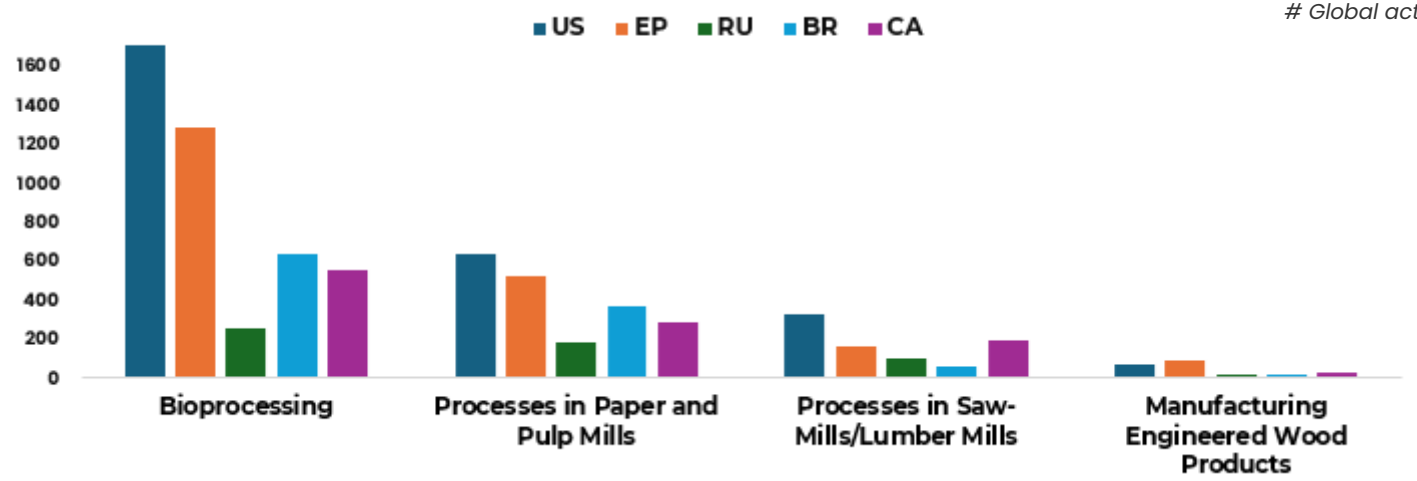
# Patent Distribution by Categories for Sustainable Bioprocessing in Key Jurisdictions (Excluding China)

*# Global active patent assets*




| Key Assignees | | | |
|---|---|---|---|
| **Bioprocessing** | **Process in Paper and Pulp Mills** | **Processes in Saw-Mills** | **Manufacturing Engineered Wood Products** |
| Xyleco Inc. (616) | Ecolab Inc. (463) | Regeneron Pharmaceuticals Inc. (627) | Krono Holding AG (131) |
| Institut Francais Du Petrole (494) | Kemira Oyj (442) | Bosch GmbH (98) | BASF SE (77) |
| Lanzatech Global Inc. (341) | Andritz AG (325) | Norwood Ind Inc. (93) | Knauf Gips KG (62) |
| Eni SpA (324) | Procter & Gamble Co. (251) | Servier SA (88) | Valinge Invest AB (35) |
| Carbon Technology Holdings LLC (220) | Solenis LLC (200) | Hitgen Inc. (83) | Berkshire Hathaway Inc. (34) |

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

*# Global active patent assets*

| Tier 1 Taxonomy Node | Tier 2 Taxonomy Node | US | EP | RU | BR | CA |
|---|---|---|---|---|---|---|
| Bioprocessing | Biological Techniques ** | 1234 | 784 | 103 | 415 | 349 |
| | Thermo-chemical Techniques ** | 1421 | 677 | 181 | 320 | 432 |
| | Biochemical Techniques ** | 452 | 280 | 48 | 223 | 139 |
| | Physical Techniques * | 229 | 122 | 23 | 71 | 71 |
| Processes in Paper and Pulp Mills | Sustainable Processes ** | 678 | 465 | 130 | 264 | 267 |
| | Pulp and Paper Processing Techniques ** | 850 | 702 | 205 | 350 | 369 |
| Processes in Saw-Mills | Sustainable Processes * | 232 | 145 | 39 | 47 | 78 |
| | Saw-Mills Processing Techniques * | 213 | 109 | 51 | 28 | 116 |
| Manufacturing Engineered Wood Products | Hot Pressing * | 160 | 152 | 29 | 24 | 61 |
| | Cold Pressing * | 29 | 20 | 3 | 6 | 13 |

** These are the top areas where Canada has filed the maximum number of patents, reflecting significant focus and investment. **However, Canada is not among the top five jurisdictions globally in these areas.**

* Areas with a lower number of patent filings across all jurisdictions. Among these low-filed areas, sustainable processes in Saw-Mills and Saw-Mills/Lumber Mills Processing Techniques are the areas where Canada is ranked among the top five jurisdictions globally.

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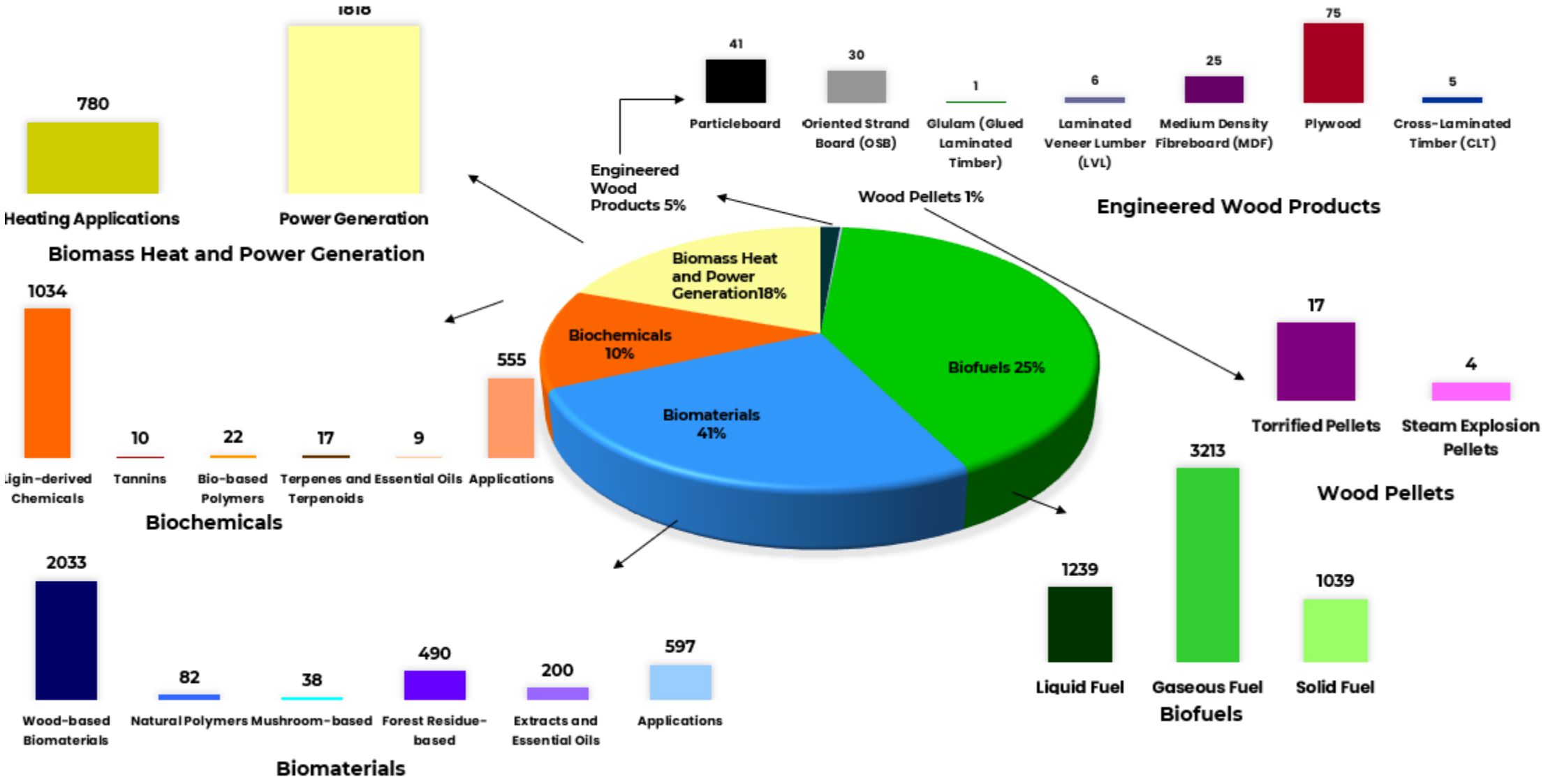
# Technology Fragmentations - Global - Value-added Products / Materials / Application

*# Global active patent families*

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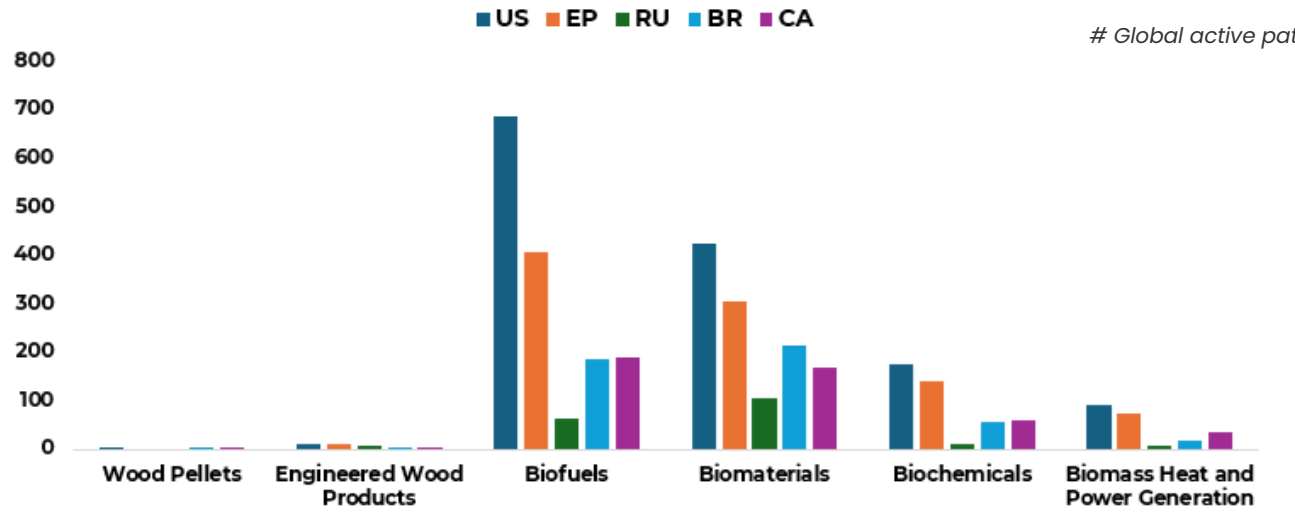
# Patent Distribution by Categories for Value-added Products/Materials/Applications in Key Jurisdictions (Excluding China)




| Key Assignees | | | | | |
|---|---|---|---|---|---|
| **Wood Pellets** | **Engineered Wood Products** | **Biofuels** | **Biomaterials** | **Biochemicals** | **Biomass Heat and Power Generation** |
| RWE Generation NL B V (24) | Xyleco Inc. (131) | Haldor Topsoe AS (99) | Fiberlean Tech Ltd. (112) | SNF Group (59) | Lanzatech New Zealand Ltd. (58) |
| Torrgas Tech BV (7) | Swiss Krono Tec AG (26) | Eastman Chem Co. (85) | IFP Energies Now (99) | Nalco Co. (41) | Ensyn Renewables Inc. (53) |
| Biocarbon Ind Sarl (7) | Flooring Technologies Ltd. (21) | Lanzatech Inc. (80) | Stora Enso Oyj (95) | Stora Enso Oyj (33) | Mcalister Technologies LLC(41) |
| Torrefusion Technologies Inc. (6) | Thomas Craig Masterman (17) | INEOS Bio SA (79) | Xyleco Inc. (78) | Anellotech Inc. (32) | Tech Resources Pty Ltd. (31) |
| Valmet Oy (3) | Marshall Medoff (17) | Carbon Tech Holdings LLC (57) | Andritz Oy (74) | Dainippon Printing Co. Ltd. (27) | |

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# Patent Distribution by Tier-3 Categories for Value-added Products/Materials/Applications in Key Jurisdictions (Excluding China) (1/2)

*# Global active patent assets*

| Tier 2 | Tier 3 | US | EP | RU | BR | CA |
|---|---|---|---|---|---|---|
| Wood Pellets | Torrefied Pellets | 6 | 6 | 0 | 4 | 4 |
| | Steam Explosion Pellets | 0 | 1 | 0 | 0 | 1 |
| Engineered Wood Products | Particleboard | 10 | 11 | 5 | 3 | 7 |
| | Oriented Strand Board (OSB) | 11 | 14 | 5 | 5 | 8 |
| | Glulam (Glued Laminated Timber) * | 0 | 0 | 0 | 0 | 0 |
| | Thermal Modified Timber * | 0 | 0 | 0 | 0 | 0 |
| | Laminated Veneer Lumber (LVL)* | 1 | 1 | 0 | 0 | 0 |
| | Medium Density Fibreboard (MDF) * | 5 | 5 | 0 | 0 | 0 |
| | Plywood | 31 | 11 | 3 | 11 | 7 |
| | Wood Fibreglass | 13 | 2 | 0 | 0 | 2 |
| | Cross-Laminated Timber (CLT) | 2 | 2 | 0 | 0 | 1 |
| Biofuels | Liquid Fuel ** | 307 | 176 | 22 | 130 | 89 |
| | Gaseous Fuel ** | 627 | 410 | 46 | 111 | 188 |
| | Solid Fuel | 253 | 92 | 8 | 28 | 57 |

** These are the top areas where Canada has filed the maximum number of patents, reflecting significant focus and investment.

* Areas with a lower number of patent filings across all jurisdictions, indicating limited global interest.

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# Patent Distribution by Tier-3 Categories for Value-added Products/Materials/Applications in Key Jurisdictions (Excluding China) (2/2)

*# Global active patent assets*

| Tier 2 | Tier 3 | US | EP | RU | BR | CA |
|---|---|---|---|---|---|---|
| Biomaterials | Wood-based Biomaterials ** | 467 | 311 | 67 | 158 | 180 |
| | Forest Residue-based Biomaterials ** | 160 | 102 | 14 | 60 | 58 |
| | Natural Polymers | 16 | 4 | 0 | 1 | 3 |
| | Extracts and Essential Oils | 61 | 35 | 3 | 13 | 16 |
| | Mushroom-based Biomaterials * | 10 | 3 | 0 | 2 | 0 |
| | Applications ** | 154 | 143 | 22 | 78 | 73 |
| Biochemicals | Lignin-derived Chemicals | 239 | 144 | 19 | 51 | 64 |
| | Terpenes and Terpenoids | 6 | 2 | 1 | 0 | 3 |
| | Tannins * | 0 | 1 | 0 | 0 | 0 |
| | Essential Oils * | 1 | 0 | 0 | 0 | 0 |
| | Bio-based Polymers | 15 | 10 | 3 | 3 | 5 |
| | Applications | 139 | 88 | 13 | 38 | 41 |
| Biomass Heat and Power Generation | Heating Applications | 172 | 96 | 15 | 26 | 43 |
| | Power Generation | 90 | 65 | 4 | 17 | 22 |

** These are the top areas where Canada has filed the maximum number of patents, reflecting significant focus and investment. **However, Canada is not among the top five jurisdictions globally in these areas.**

* Areas with a lower number of patent filings across all jurisdictions, indicating limited global interest. Canada is also not focusing on these areas. This presents a valuable opportunity to file patents in these niche domains.

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# Canadian Insights

## Module B & Module C

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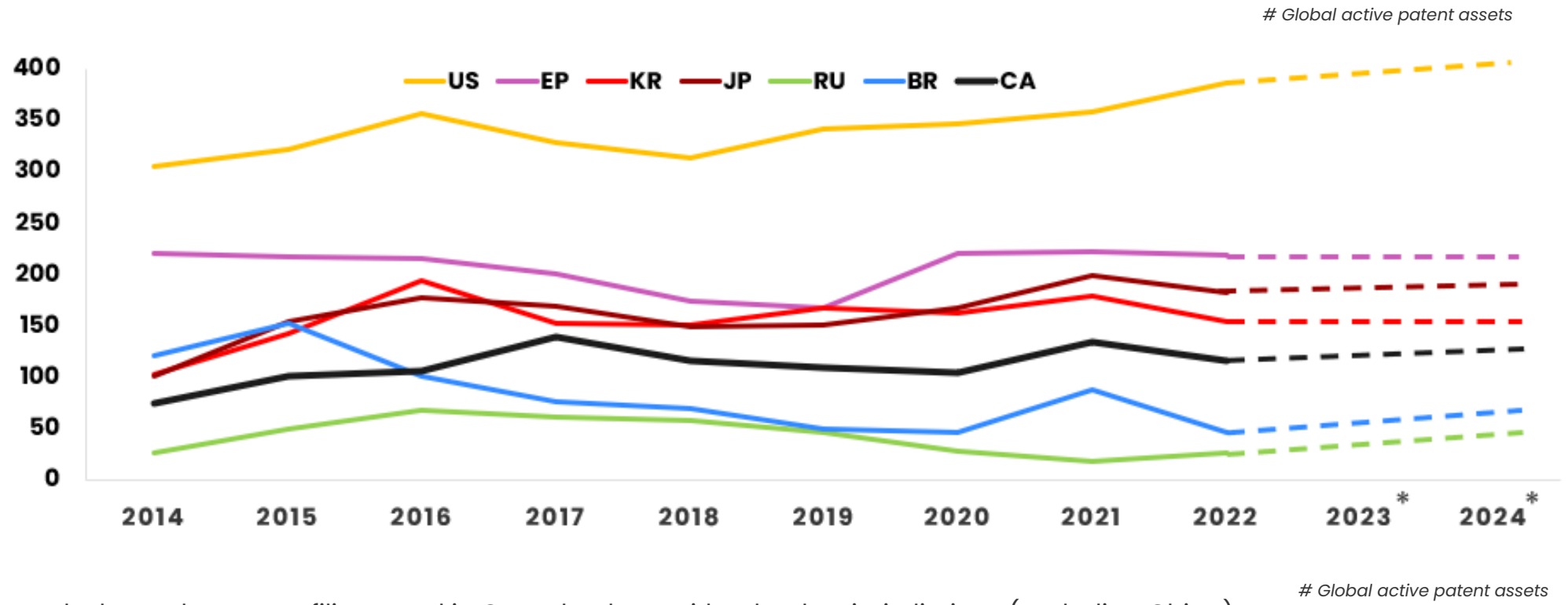
# Canadian vs. International Filings (excluding China)




# Global active patent assets

- The above graph shows the patent filing trend in Canada along with other key jurisdictions (excluding China).
- Canada has significantly fewer filings as compared to other key jurisdictions, such as the United States and Europe. The average number of filings in Canada has been ~75. In contrast, the United States and 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 more 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.

***Notes:***

1. ** projected numbers have been shown for the years 2023-2024, as the numbers may increase as some of the applications filed during this period may not have been published yet.*
2. *The entire data (previous analysis' data + data published after the last study) is considered for the graphs.*

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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 based out of Russia have filed 199 patent families. The countries are chosen based on the highest forest cover regions.

*# Global active patent assets*

| Global Patent Insights/Country | Russian Assignees | Brazilian Assignees | Chinese Assignees | US Assignees | Canadian Assignees |
|---|---|---|---|---|---|
| **Patent Families** | 199 | 223 | 13,723 | 1,755 | 247 |
| **Expanded Dataset** | 207 | 370 | 14,482 | 8,050 | 942 |
| **Granted Patents** | 171 | 136 | 6,627 | 5,454 | 576 |
| **Pending Applications** | 2 | 221 | 3,634 | 2,586 | 365 |
| **Utility Models** | 24 | 13 | 4,221 | 10 | 1 |
| **Key Assignees** | Fed Gosudarstvennoe Unitarnoe Predpriyatie Tsentr Ekspluatatsii Obektov Nazemnoj Kosmicheskoj Infras<br>Sharapov Evgenij Sergeevich | Klabin S A<br>Oliveira Juarez Souza<br>De Petróleo Brasileiro S.A. – Petrobras<br>Petroleo Brasileiro S.A. Petrobras | Chinese Academy of Science<br>State Grid Corp. of China<br>Wuhan Kaidi Eng Technology Res Inst Co.<br>Univ Qilu Technology | Xyleco Inc.<br>Nalco Co.<br>Procter & Gamble<br>Lanzatech Inc.<br>Eastman Chem Co. | Anaergia Inc.<br>FPI Innovations Iogen Corp.<br>Norwood Ind Inc.<br>Suzano Canada Inc.<br>Comet Biorefining Inc.<br>Enerkem Inc. |
| **Key Jurisdictions** | RU, US, WO, EP | BR, US, EP, AR | CN, US, WO, EP | US, EP, CA, CN | US, CA, EP, BR |

*Notes:*

1. *INPADOC families are considered for this report - An INPADOC patent family encompasses all patent documents that share a priority relationship, either directly or indirectly (via a third document).*
2. *Expanded dataset is the sum of granted patents, pending applications and utility models.*

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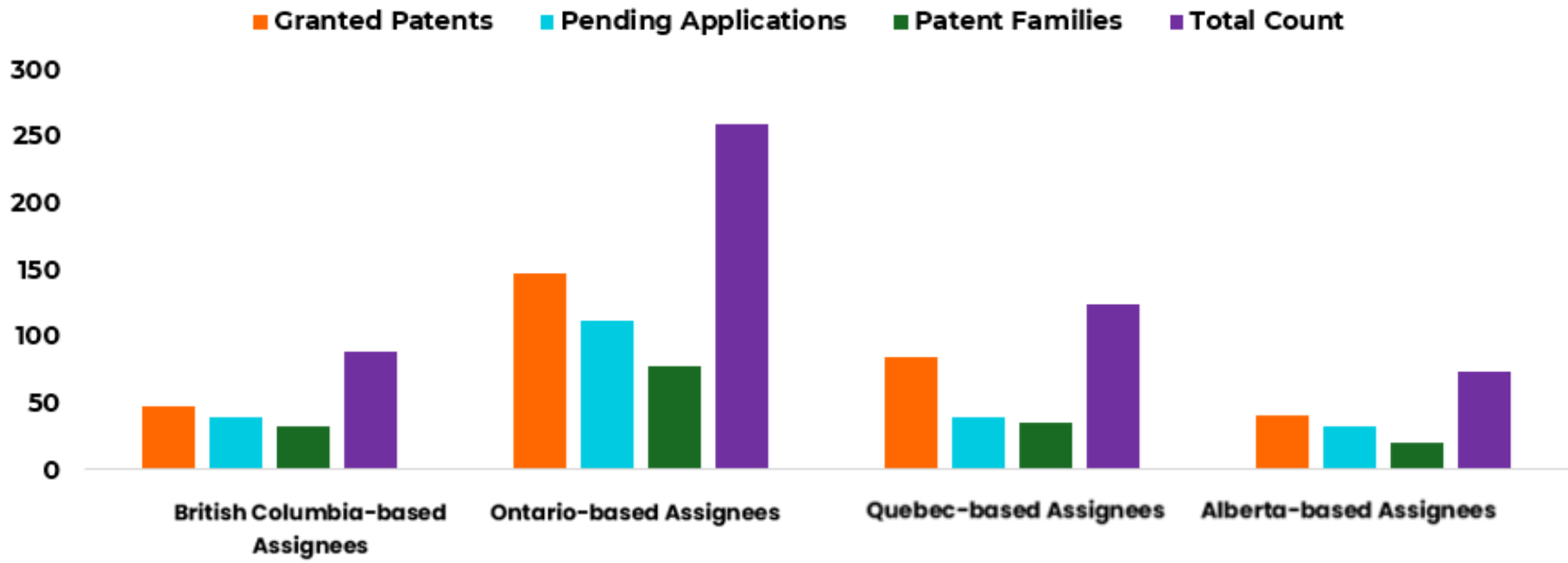
# BC vs Other Provinces




- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia, Alberta, Ontario, and Quebec. Ontario-based companies seem to have filed more patents than companies in other Canadian provinces.
- BC-based companies have maximum filings in Pyrolysis and Carbonization, Sorting and Scaling, and Bucking, whereas Alberta-based companies have more filings in Pyrolysis and Carbonization, Gasification, and Fermentation.
- West Fraser Mills Ltd. is the top assignee in BC; Anaergia Inc. in Ontario, FPI Innovations in Québec, and Enlighten Innovations Inc. in Alberta.

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# Patent Litigations

This section includes major patent disputes, infringement cases, and legal trends shaping the competitive landscape.

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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 | Filing Date | Patent Details | Technology | Source | Status |
|---|---|---|---|---|---|---|---|
| Andritz Inc. | Engineering Company | Cortex N. Am. Corp. | July 30, 2021 | US7159626, US7506674, US7681609, US8082958 | Wood working knives and clamping assemblies | Source | Closed |
| 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 United States; 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 filings 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

**This section provides an analysis of future market trends, growth projections, and key drivers influencing the industry's trajectory.**

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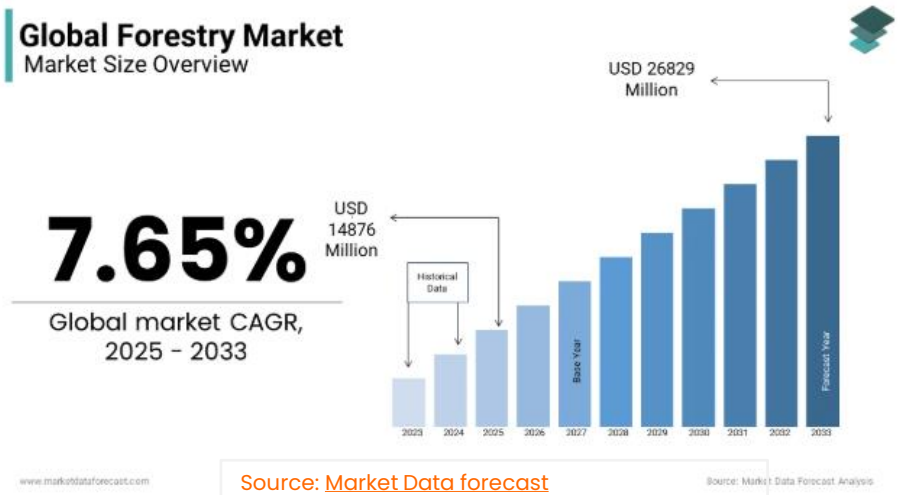
# Market Forecast (1/2)

### Sustainable Forest Management

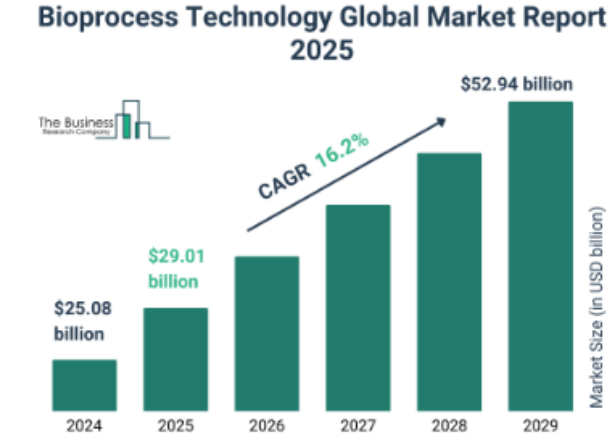
- The global forest management market was valued at US **$13819.19 million in 2024** and is projected to grow to US **$14876 million in 2025** from **US $26829 million by 2033**, growing at a **CAGR of 7.65%**. (Source)




Source: Market Data forecast

### Sustainable Bioprocessing

- The global upstream bioprocessing equipment market is on a robust growth trajectory, with sales expected to surge from **$25.08 billion in 2024** to **$29.01 billion in 2025** at a **compound annual growth rate (CAGR) of 15.7%**. (Source)
- The global market for forest bioproducts is estimated to reach **USD 36,249.3 million by 2035**. (Source)




Source: The Business Research Company

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# Market Forecast (2/2)

**Engineered Wood Products**

- The engineered wood products market size is forecast to **increase by USD 7.46 billion at a CAGR of 7.1% between 2024 and 2029**. (Source)


Source: Technavio

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# Key Players

The key players are identified based on their market presence, active patent activity, and insights from various studies. These companies or entities have a significant influence on the industry through innovation, product offerings, and strategic positioning.

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# Key Players

## Module A – Sustainable Forest Management

**The key players are identified based on their market presence (scale of operations, revenue, partnerships, and global/regional footprint), Technological Innovation (patent activity, R&D efforts, and adoption of advanced or sustainable technologies), and insights from various studies. These companies or entities have a significant influence on the industry through innovation, product offerings, and strategic positioning.**

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# Key Players – Sustainable Forest Management (1/3)

The table below 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 surveys, etc. (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) |
| 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) |
| 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) |
| 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) |
| 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 forest assets. (Source) |

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# Key Players – Sustainable Forest Management (2/3)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| 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) |
| EOS Data Analytics | USA | Forest Management, Forest Monitoring | EOS Data Analytics provides 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 provides forest monitoring solutions that utilize data from optical satellites, synthetic aperture radar (SAR), and light detection and ranging (LiDAR). (Source) |
| Enviva | United States | Forest Management, Forest Monitoring | Enviva Biomass specializes in sustainable forest management and the production of wood pellets as a renewable alternative to coal. (Source) |
| Ponterra | UK | Forest Management, Forest Monitoring | Ponterra focuses on transforming degraded cattle pastures back into rainforests, particularly in regions like Panama. (Source) |

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# Key Players – Sustainable Forest Management (3/3)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| Re.green | Brazil | Ecological Balance, Biodiversity | A Brazilian enterprise that emphasizes the restoration of degraded lands using native species and incorporates strong social components. (Source) |
| Flai | Slovenia | Forest Management, Forest Monitoring | A Slovenian startup specializing in forestry inventory using LiDAR data. Flai's web application employs proprietary artificial intelligence models to classify forest elements, including ground cover, vegetation layers, and tree trunks. (Source) |

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# Key Players

## Module B – Sustainable Bioprocessing

**The key players are identified based on their market presence (scale of operations, revenue, partnerships, and global/regional footprint), Technological Innovation (patent activity, R&D efforts, and adoption of advanced or sustainable technologies), and insights from various studies. These companies or entities have a significant influence on the industry through innovation, product offerings, and strategic positioning.**

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# Key Players – Sustainable Bioprocessing (1/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| 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) |
| 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) |
| 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 develops sustainable and biodegradable polymers, plastics, and products from renewable carbon sources, including waste. (Source) |

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# Key Players – Sustainable Bioprocessing (2/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| Canary Biofuels Inc | Canada | Biodiesel | Canary Biofuels comprises multiple biorefineries across Canada for converting biowastes into biofuels. (Source) |
| 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) |
| 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 utilizes agricultural wastes and wood wastes for producing biochemicals. (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) |

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# Key Players – Sustainable Bioprocessing (3/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| Char Technologies | Canada | Biochar, Syngas, Biocoal | Char Technologies implements a 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) |
| Expander Energy | Canada | Gasification | Expander Energy uses its novel gasification technology to convert forest residues into fuels. (Source) |
| 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 and sustainable forest management policies for the manufacturing and processing of the pulp and paper products. (Source) |

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# Key Players – Sustainable Bioprocessing (4/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| 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 in around 150 countries. (Source) |
| 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 wood composites, pulp, tissue and paperboard packaging, graphic paper, and personal care. (Source) |

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# Key Players – Sustainable Bioprocessing (5/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| 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 policies for the processes. (Source) |
| novozymes | Denmark | Enzymes-based Pulp and Paper Production | Novozymes utilizes enzymes for pulp mills, bleach plants and stock preparation to reduce the mill's energy footprint and environmental impact. (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) |
| Constructive Bio | England | Pesticides, Biodegradable Plastics | Constructive Bio is pioneering the development of novel chemical building blocks not found in nature, aiming to create sustainable microbial factories. (Source) |
| Novonesis | Denmark | Renewable Energy | Novonesis has introduced several sustainable biosolutions. Initiatives include Cell-Tech, which enhances soybean yields through nitrogen-fixing bacteria, and collaborating with Carbios to produce PET-degrading enzymes. (Source) |

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# Key Players – Sustainable Bioprocessing (6/6)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| Evolved by Nature | USA | Sustainable Skincare | Addressing sustainability challenges in the beauty industry, Evolved by Nature has developed Activated Silk™ technology. (Source) |
| CMPC | Chile | Pulp and Paper, Biodegradable Fibre, Cellulose | CMPC manufactures pulp and paper products, biodegradable Fibre, cellulose, and other bioproducts by using sustainable processes. (Source) |

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# Key Players

## Module C – Value-added Products/Materials/Applications

**The key players are identified based on their market presence (scale of operations, revenue, partnerships, and global/regional footprint), Technological Innovation (patent activity, R&D efforts, and adoption of advanced or sustainable technologies), and insights from various studies. These companies or entities have a significant influence on the industry through innovation, product offerings, and strategic positioning.**

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# Key Players – Value-added Products/Materials/Applications (1/2)

The table below 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 Fibreboard (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 utilizes the byproducts and residuals from its saw-mills to produce energy, heating, and pulp and paper as part of their sustainability initiative. (Source) |
| Peak Renewable | Canada | Wood Pellets, Renewable Energy | In August 2024, Peak Renewables, in partnership with Rex Lumber, commenced operations of a new pellet mill in Dothan, Alabama. (Source) |
| Drax | England | Wood Pellets, Biomass Power Plants | A significant player in the biomass energy sector, Drax reported a 5% increase in wood pellet production for 2024. The company is also exploring investments of up to $12.5 billion in developing biomass power plants with carbon capture and storage (BECCS) technology in the United States over the next decade. (Source) |

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# Key Players – Value-added Products/Materials/Applications (2/2)

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

| Companies | Country | Technology Focus | Description |
|---|---|---|---|
| Freres Engineered Wood | USA | Engineered Wood Products | Freres expanded its product offerings, including new plywood panel sizes and laminated veneer lumber (LVL) products. Notably, their Mass Ply Panels (MPP) were featured in the construction of Portland International Airport's new terminal, showcasing the versatility and sustainability of their engineered wood products. (Source) |
| 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 the production of green electricity from biowaste from the wood processing. (Source) |

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# Key Mergers And Acquisitions

This section highlights prominent mergers, acquisitions, and strategic alliances that impact market dynamics. These strategic decisions help in driving consolidation, expanding market reach, enhancing technological capabilities, and strengthening competitive positioning.

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# Key Mergers And Acquisitions

## Module A – Sustainable Forest Management

**This section highlights prominent mergers, acquisitions, and strategic alliances that impact market dynamics. These strategic decisions help in driving consolidation, expanding market reach, enhancing technological capabilities, and strengthening competitive positioning.**

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

The table below 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 expand the Trimble Connected Forest solutions, which offer a complete end-to-end ecosystem for forest management, traceability, and timber processing. | Source |
| PRT Growing Services Ltd. (Headquarter – Canada) | International Forest Company (Headquarter – USA) | 2023 | RT Growing Services Ltd. (“PRT”) today announced its acquisition of International Forest Company (“IFCO”), based in the United States Southeast, accelerating the company’s growth and establishing PRT as North America’s leading provider of premium-quality container and bareroot seedlings. | 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 and Acquisitions - Sustainable Forest Management (2/3)

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

| Primary Entity | Secondary Entity | Year | Details | Source |
|---|---|---|---|---|
| **Mirax Group (Headquarter – Canada)** | **Lyle Forest Products (Headquarter – Canada)** | 2023 | Mirax Group announced that it has reached an agreement to acquire Lyle Forest Products ("Lyle"), located in Chilliwack, BC. This acquisition is one step closer for Mirax Group to becoming a more vertically integrated forest company in British Columbia. With the addition of Lyle to our family of companies, this is consistent with our Value-added business model to further enhance and diversify investment locally in BC and produce high-quality finished products ready to be shipped globally. | 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 |

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

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

| Primary Entity | Secondary Entity | Year | Details | Source |
|---|---|---|---|---|
| Averon Park (Headquarter – UK) | Foresight Sustainable Forestry Company (Headquarter – UK) | 2024 | Averon Park Limited announced its intention to acquire FSF, a UK-based entity focused on sustainable forestry investments. The proposed acquisition, valued at 97 pence per share, underscores the increasing consolidation within the sustainable forestry sector. | Source |
| New Forests (Headquarter – Australia) | US Forestry Assets (Headquarter – USA) | 2024 | Throughout 2024, New Forests, an Australia-headquartered asset manager specializing in nature-based investments, continued to expand its portfolio in the United States. Notably, in 2023, the firm acquired the 19,000-acre McCloud Forest in California, demonstrating its commitment to sustainable forestry investments in the region. | 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 |

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# Key Mergers And Acquisitions

## Module B – Sustainable Bioprocessing

**This section highlights prominent mergers, acquisitions, and strategic alliances that impact market dynamics. These strategic decisions help in driving consolidation, expanding market reach, enhancing technological capabilities, and strengthening competitive positioning.**

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# Key Mergers and Acquisitions - Sustainable Bioprocessing (1/3)

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

| Primary Entity | Secondary Entity | Year | Details | 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 the decarbonizing of natural gas. Airdep S.R.L. is a provider of biogas desulfurization and air deodorization products based in Vicenza, Italy. | Source |
| Mondi (Headquarter – United Kingdom) | Hinton Pulp Mill (Headquarter – Canada) | 2023 | Mondi produces sustainable packaging and paper. It acquired the 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, which helped create high-quality, sustainable wood products. | 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 (online and benchtop 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 adds capabilities in lumber and tissue for Paper Excellence. | Source |

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# Key Mergers and Acquisitions – Sustainable Bioprocessing (2/3)

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

| 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 |
| 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 has acquired Greenergy's Canadian operations as well. | 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 |

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# Key Mergers and Acquisitions - Sustainable Bioprocessing (3/3)

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

| Primary Entity | Secondary Entity | Year | Details | Source |
|---|---|---|---|---|
| Thermo Fisher Scientific (Headquarter – USA) | Solventum (Headquarter – USA) | 2025 | In February 2025, Thermo Fisher Scientific announced its intention to acquire Solventum's purification and filtration division for approximately $4.1 billion. | Source |
| Lessafre (Headquarter – United Kingdom) | Altar (Headquarter – Canada) | 2025 | In 2024, Lesaffre, a global leader in fermentation and microorganisms, acquired Altar, a French startup specializing in Adaptive Laboratory Evolution (ALE). This strategic move aims to bolster Lesaffre's innovation capabilities in fermentation technologies, aligning with sustainable bioprocessing objectives. | Source |
| Certis Biological (Headquarter – USA) | AG Biome (Headquarter – USA) | 2022 | Certis Biologicals acquired multiple assets from AgBiome, including notable fungicides such as Howler® and Theia®. | 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 And Acquisitions

## Module C – Value-added Products/Materials/Applications

**This section highlights prominent mergers, acquisitions, and strategic alliances that impact market dynamics. These strategic decisions help in driving consolidation, expanding market reach, enhancing technological capabilities, and strengthening competitive positioning.**

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# Key Mergers and Acquisitions - Value-added Products/Materials/Applications (1/2)

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

| Primary Entity | Secondary Entity | Year | Details | Source |
|---|---|---|---|---|
| Drax Canada (Drax Group Headquarter – UK) | Pinnacle Renewable Energy (Headquarter – Canada) | 2021 | Drax acquired Pinnacle Renewable Energy Inc., major producer and supplier of good-quality, compressed bioenergy pellets. | Source |
| Resolute (Headquarter – Canada) | Conifex Timber (Headquarter – Canada) | 2020 | Resolute Forest Products produces a diverse range of wood, pulp, tissue, and paper products. Resolute acquired Conifex's three United States saw-mills. This acquisition helped Resolute to increase its lumber production, specifically in the United States 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 byproducts. West Fraser, a diversified wood products company, acquired Spray Lake Saw-mills to expand its operating footprint in Alberta. | 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 percent 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 production and expand into Eastern Canada. | Source |

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# Key Mergers and Acquisitions - Value-added Products/Materials/Applications (2/2)

The table below 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 |
| 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 |
| James Jones & Sons Ltd. (Headquarter – UK) | HG Timber (Headquarter – UK) | 2024 | In October 2024, James Jones & Sons Ltd. expanded its UK pallets and packaging division by acquiring HG Timber Ltd. This acquisition aimed to enhance the company's product offerings and market reach within the engineered wood products sector. | Source |

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# Key Canadian Startups

This section includes emerging Canadian companies driving innovation and growth in the sector. They are selected based on market presence, active patent activity, technological advancements, and industry impact.

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# Key Canadian Startups

**This section highlights Key Canadian startup companies. The companies are shortlisted on various factors like funding (level and sources of investment indicating scalability and investor confidence), Market Potential (size and growth prospects of the target market), Technology Differentiation (uniqueness and competitiveness of the startup's technology), Industry Partnerships (collaborations that enhance credibility and market access), Commercial Growth (business traction through revenue, customer base, or expansion), *etc.***

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# Key Canadian Startups – British Columbia (1/3)

| Company | Industry | Company | Industry |
|---|---|---|---|
| Bast Fiber Tech | Biomaterials/Bioproducts | Drax Group Canada - Pinnacle Renewable Energy Group | Wood Pellets |
| Andion Group | Bioprocessing | Harmac | Pulp & Paper Mills |
| Arbios Biotech | Biofuel & Biogas Processing | FTS Forest Tech | Forest Management |
| Arterran Renewables | Biofuels | NorthPac Forestry GroupLtd. | Harvesting Operations |
| BC Biocarbon | Biochar & Solid Carbon | Reforus | Biochemicals |
| Calmura Natural Walls | Engineered Wood Products | Tolko | Value Added Manufacturing |
| Canfor | Saw & Lumber Mills | Zanzibar Holdings Ltd. | Forest Replanting & Silviculture |
| Bella Biochar Corporation | Biochar & Solid Carbon | Flash Forest | Forest Management |
| FireRein | Biochemicals | BioForest | Forest Replanting & Silviculture |
| CH Four Biogas | Biofuel & Biogas Processing | Ecostrat | Harvest Residuals |
| Commercial Bioenergy Inc. | Biomass Heat & Power Generation | Element5 | Engineered Wood Products |

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# Key Canadian Startups – Ontario (2/3)

| Company | Industry | Company | Industry |
|---|---|---|---|
| BioDiffusion Technologies | Biomaterials/Bioproducts | Forge Hydrocarbons | Biofuel & Biogas Processing |
| Comet Biorefining | Bioprocessing | Char Technologies | Biochar & Solid Carbon |
| Timmerman Timberworks | Engineered Wood Products | Origin Materials | Bioprocessing |
| Bioenergy Solutions Inc. | Biochar & Solid Carbon | Treeera | Forest Replanting & Silviculture |
| Fluid Energy Group | Biochemicals | Silvacom FMS | Harvesting Operations |
| Canary Biofuels | Biofuel & Biogas Processing | Alberta Pacific Forest Products Inc. | Pulp & Paper Mills |
| Molten Arbour | Biomass Heat & Power Generation | Innovative Reduction Strategies Inc. (IRSI) | Pyrolysis & Carbonization |
| Carbon OxyTech Inc. | Bioprocessing | Rainforest Energy | Biofuel & Biogas Processing |
| Western Archib | Engineered Wood Products | Sixring Inc | Bioprocessing |
| Wild and Pine | Forest Management | RAW Biochem | Biochemicals |

Refer to Appendix for Complete List

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# Key Canadian Startups – Other Provinces (3/3)

| Company | Industry | Company | Industry |
|---|---|---|---|
| Carbon Lock Technologies | Biochar & Solid Carbon | Arbec Forest Products | Engineered Wood Products |
| Enerkem Inc. | Biochemicals | Remsoft | Harvesting Operations |
| Cellufuel | Biofuel & Biogas Processing | Pyrovac | Pyrolysis & Carbonization |
| Meadow Lake Tribal Council's (MLTC) bioenergy plant | Biomass Heat & Power Generation | Kruger Inc. | Value Added Manufacturing |
| AecopaQ | Biomaterials/Bioproducts | Granules LG | Wood Pellets |
| ALC Bio Innovations Inc. | Bioprocessing | Titan Carbon Smart Technologies | Biochar & Solid Carbon |
| ClimaTECH Innovations Inc. | Forest Replanting & Silviculture | Innoltek | Biofuel & Biogas Processing |

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# Key Partnerships

Strategic collaborations that drive innovation, market expansion, and competitive advantage. It includes industry alliances, R&D agreements, and supply chain partnerships.

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# Key Partnerships

## Module A – Sustainable Forest Management

**This section highlights prominent business partnerships, and strategic collaborations that drive innovation, market expansion, and competitive advantage. It includes industry alliances, R&D agreements, and supply chain partnerships.**

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# Key Partnerships - Sustainable Forest Management (1/2)

The table below shows the key partnerships between different companies:

| Entity 1 | Entity 2 | Year | Description | Source |
|---|---|---|---|---|
| Remsoft (Headquarter – Canada) | ForestX (Headquarter – Sweden) | 2020 | Remsoft entered a Scandinavian partnership with ForestX to improve forest management and supply chain planning. | 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 |
| 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 a strategic alliance with Hummingbird Drones for wildfire analysis. | 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 expand 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 - Sustainable Forest Management (2/2)

The table below shows the key partnerships between different companies:

| Entity 1 | Entity 2 | Year | Description | 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 |
| Drax Group (Headquarter – England) | United States Timberland Managers (Headquarter – USA) | 2024 | Drax, a power producer, announced plans to build wood-fired power plants in the United States pine belt, collaborating with major timberland managers to source wood sustainably for bioenergy with carbon capture and storage (BECCS) facilities. | Source |
| Drax Group (Headquarter – England) | Molpus Woodlands Group (Headquarter – USA) | 2024 | Drax Group partnered with Molpus Woodlands Group to secure sustainably sourced woody biomass for its bioenergy with carbon capture and storage (BECCS) operations in the southeastern United States. This collaboration aims to support Drax's goal of capturing 6 million metric tons of carbon annually in the United States | Source |
| IKEA (Headquarter – Netherlands) | International Union of Forest Research Organizations (IUFRO) (Headquarter – Austria) | 2024 | IKEA became a partner of the IUFRO World Congress 2024, demonstrating its commitment to responsible forest management and the promotion of sustainable wood sourcing practices globally. | Source |

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# Key Partnerships

## Module B – Sustainable Bioprocessing

**This section highlights prominent business partnerships, and strategic collaborations that drive innovation, market expansion, and competitive advantage. It includes industry alliances, R&D agreements, and supply chain partnerships.**

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# Key Partnerships – Sustainable Bioprocessing (1/3)

The table below 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 |
| **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 |
| **EcoSynthetix (Headquarter – Canada)** | **Dow (Headquarter – USA)** | 2022 | Dow partnered with EcoSynthetix to expand bio-based offerings to the global personal care market. | Source |

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# Key Partnerships – Sustainable Bioprocessing (2/3)

The table below shows the key partnerships between different companies:

| Entity 1 | Entity 2 | Year | Description | Source |
|---|---|---|---|---|
| Enerkem (Headquarter – Canada) | SHV Energy (Headquarter – Netherlands) | 2023 | Canadian 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 decarbonization 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 |
| 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 |
| 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 |
| Blue Biofuels (Headquarter – USA) | Vertimass (Headquarter – USA) | 2024 | Blue Biofuels partnered with Vertimass Forge to start production of sustainable aviation fuel. | Source |

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# Key Partnerships – Sustainable Bioprocessing (3/3)

The table below shows the key partnerships between different companies:

| Entity 1 | Entity 2 | Year | Description | Source |
|---|---|---|---|---|
| Drax Group (Headquarter – England) | Pathway Energy Agreement (Headquarter – USA) | 2024 | Drax signed a supply agreement with Pathway Energy to provide over a million tons of biomass annually from its plants in Louisiana and Mississippi to Pathway's new facility in Texas. This plant will produce sustainable aviation fuel, reducing emissions by 80%, and is equipped with carbon capture technology. | Source |
| Drax Group (Headquarter – England) | Molpus Woodlands Group (Headquarter – USA) | 2024 | In addition to their collaboration in sustainable forest management, Drax Group's partnership with Molpus Woodlands Group also focuses on supplying biomass for sustainable bioprocessing initiatives, particularly in the production of renewable energy through BECCS technology. | Source |
| IKEA (Headquarter – Netherlands) | WWF (Headquarter – Switzerland) | 2024 | IKEA and WWF continued their long-term partnership, focusing on sustainable bioprocessing practices within the forestry sector to enhance biodiversity and promote responsible resource use. | Source |

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# Key Partnerships

## Module C – Value-added Products/Materials/Applications

**This section highlights prominent business partnerships, and strategic collaborations that drive innovation, market expansion, and competitive advantage. It includes industry alliances, R&D agreements, and supply chain partnerships.**

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# Key Partnerships – Value-added Products/Materials/Applications

The table below 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 |
| 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 |
| Power Wood (Headquarter – Canada) | Squiala First Nation (Headquarter – Canada) | 2024 | Power Wood Corporation, in partnership with Squiala First Nation, was awarded $3.4 million from the BC Manufacturing Jobs Fund (BCMJF) to build a new thermal modification facility that will produce high-value, thermally modified wood products. | Source |

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# Key Investments

Prominent funding activities, venture capital infusions, and strategic investments shaping market growth and innovation.

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# Key Investments

## Module A – Sustainable Forest Management

**This section highlights prominent funding activities, venture capital infusions, and strategic investments shaping the market growth and innovation.**

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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 in funding for the forest truck automation project. | 2024 | Source |
| **Treeera (Headquarter – Canada)** | Treefera raised $12M in Series A for an 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

**This section highlights prominent funding activities, venture capital infusions, and strategic investments shaping the market growth and innovation.**

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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 a $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 its plans to expand its production of low-carbon industrial and agricultural products made from biomass. | 2023 | Source |
| **Anaergia (Headquarter – Canada)** | Anaergia, a Canadian 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) | The Ministery of Natural Resources of Canada announced a $10 million contribution to BioLesna Carbon Technologies LP, a joint venture between BC Biocarbon and Dunkley LumberLtd., 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) | The 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 a $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 |
| 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 |

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# Key Investments – Sustainable Bioprocessing (3/3)

| Companies | Description | Year | 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

**This section highlights prominent funding activities, venture capital infusions, and strategic investments shaping the market growth and innovation.**

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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)** | The 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 |
| **Power Wood, in partnership with Squiala First Nation** | Power Wood Corporation, an Agassiz, B.C.-based manufacturer of specialty wood products, in partnership with Squiala First Nation, was awarded $3.4 million from the BC Manufacturing Jobs Fund (BCMJF) to build a new thermal modification facility that will produce high-value, thermally modified wood products. | 2024 | Source |
| **British Columbia's Institute of Technology (BCIT)** | BCIT received $995,000 to construct the Robert Bosa Carpentry Pavilion, a two-story mass timber building with glulam and CLT elements. This zero-carbon, LEED Gold-certified facility will serve as an educational hub for mass timber and hybrid construction, supporting B.C.'s climate goals. | 2025 | Source |

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# Emerging Technologies

Innovative advancements shaping the industry's future, driving efficiency, sustainability, and market evolution.

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# Emerging Technologies – Sustainable Forest Management (1/2)

| Emerging Technologies | Impact on Market |
|---|---|
| **Internet of Things (IOT)** | • Enables the implementation of the real-time monitoring of the forest environment in terms of tracking fire accidents, monitoring the health of the crop, continuous assessment of the vegetation, and real-time tracking of forest logging.<br>• 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.<br>• AI-enabled bots may make decisions related to harvesting operations, e.g., which tree to fell, where to perform logging activities, etc.<br>• Helps in mapping and monitoring CO2 stock and other ecosystem services.<br>• The 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<br>• Provides a secure and transparent method of tracking and verifying the origin and movement of forest products.<br>• 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.<br>• Implements and monitors forest health treatments and builds predictive models for the early detection of disturbances like forest fires.<br>• 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) |
| **Remote Sensing and LiDAR** | • Remote sensing technologies, including Light Detection and Ranging (LiDAR), provide high-resolution data on forest structure and composition. LiDAR, often deployed via drones or satellites, generates detailed 3D maps of forest canopies, aiding in biomass estimation and carbon stock assessments.<br>• These insights support informed decision-making for conservation and resource management. (Source) |

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# Emerging Technologies – Sustainable Forest Management (2/2)

| Emerging Technologies | Impact on Market |
|---|---|
| **Drone Technology for Reforestation** | • Drones equipped with seed-dispensing mechanisms are revolutionizing reforestation efforts.<br>• These drones can rapidly plant seeds over large, inaccessible areas, accelerating forest regeneration after events like wildfires.<br>• Companies such as DroneSeed have demonstrated the effectiveness of this approach in restoring thousands of acres within short timeframes. (Source) |
| **Climate-Smart Forestry (CSF)** | • CSF integrates advanced information technologies to develop proactive forest management methods addressing climate change challenges.<br>• By leveraging AI and data analytics, CSF enhances decision-making processes, ensuring forests contribute to climate mitigation and adaptation goals. (Source) |

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# Emerging Technologies – Sustainable Bioprocessing and Value-added Products (1/2)

| 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.<br>• 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.<br>• The 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 also actively remove carbon dioxide ($CO_2$) from the atmosphere.<br>• This approach is essential for combating climate change and promoting sustainability.<br>• 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.<br>• 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.<br>• 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, the global bioprocess market is expected to grow at a CAGR of 14.8% from USD 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.<br>• These sensors provide real-time data, allowing for immediate detection of any deviations from optimal conditions.<br>• 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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# Emerging Technologies – Sustainable Bioprocessing and Value-added Products (2/2)

| Emerging Technologies | Impact on Market |
|---|---|
| **Single-use Technologies** | • The adoption of single-use bioreactors and disposable process equipment has increased due to their cost-efficiency and flexibility, reducing the need for cleaning and sterilization between batches. (Source) |
| **High-efficiency Drying and Pelletizing Methods** | • New manufacturing technologies, such as advanced drying and pelletizing techniques, have optimized energy use and reduced waste, enhancing the quality and sustainability of wood pellet production. (Source) |
| **Mass Timber Construction** | • The development of mass timber products, such as cross-laminated timber (CLT), has enabled the construction of large-scale wooden structures.<br>• For example, Stockholm's "Wood City" project aims to build the world's largest timber city, showcasing the potential of engineered wood in urban development. (Source) |

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# Relevant Standards and Standard Essential Patents

This section includes key industry standards and SEPs that define compliance, interoperability, and innovation in the sector.

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# Relevant Standards and Role of Standard Essential Patents (1/2)

**Standard Essential Patent**

A Standard Essential Patent (SEP) is a patent granted for a technological invention that is essential for the implementation and working of a standard. Patents that 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 use relevant standards (generally, such technology standards are mandatory or important for relevant product/technology; therefore, the 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 want to use those inventions in their products/services. Such SEPs related to telecom technologies may also be applicable in the 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 the role of SEPs in Forest Bioeconomy sector is explained in the subsequent slide.

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# Relevant Standards and Role of Standard Essential Patents (2/2)

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

This section includes market trends, key players, investments, and policy impacts specific to British Columbia.

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# British Columbia-based Patent Insights

**This section highlights patent trends, key players, and key inventors-related insights specific to British Columbia.**

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# British Columbia-based Assignees and Inventors Patent Insights– Sustainable Forest Management

| | British Columbia-based Assignees | British Columbia-based Inventors | Ontario-based Assignees | Ontario-based Inventors |
|---|---|---|---|---|
| **Patent Families** | 6 | 5 | 16 | 17 |
| **Expanded Dataset** | 19 | 17 | 163 | 42 |
| **Granted Patents** | 16 | 1 | 120 | 10 |
| **Pending Applications** | 3 | 16 | 41 | 32 |
| **Top Assignees** | Terramera Inc., Sensenet Inc., Mda Ltd., Teledyne Technologies Incorporated, Urthecast Corp. | Terramera Inc., Sensenet Inc., Mda Ltd., Urthecast Corp., Skyscope Corp. | AI Inc., Bobsweep Inc., First Resource Management Group Inc., Corteva Agriscience | University of Toronto, First Resource Management Group Inc., Aquanty Inc., National Research Council Canada |
| **Top Jurisdictions** | US, CA, EP | US, CA, EP | US, CA, EP | US, CA, EP |
| **Top Categories** | GIS/Satellites, Drone/UAV, Real-time Natural Hazards Monitoring and Management | GIS/Satellites, Carbon Footprint Tracking, Drone/UAV | Forest Inventory Management, Drone/UAV, LiDAR | Drone/UAV, Land Characteristics Assessment, Forest Inventory Management |

- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia, Alberta, Ontario and Quebec. Ontario-based companies seem to have filed more patents as compared to the other Canadian provinces. No significant patent filings were observed for Quebec- and Alberta-based companies/inventors.

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# British Columbia-based Assignees Patent Insights- Sustainable Bioprocessing and Value-added Products/Materials/Applications

| | British Columbia-based Assignees | Ontario-based Assignees | Quebec-based Assignees | Alberta-based Assignees |
|---|---|---|---|---|
| **Patent Families** | 33 | 77 | 36 | 20 |
| **Expanded Dataset** | 88 | 259 | 124 | 73 |
| **Granted Patents** | 47 | 147 | 84 | 41 |
| **Pending Applications** | 40 | 112 | 40 | 32 |
| **Top Assignees** | West Fraser Mills Ltd., River Basin Energy Inc., G4 Insights Inc. | Anaergia Inc., Iogen Corp, Comet Biorefining Inc., Norwood Ind Inc., University of Western Ontario | FPI Innovations , Enerkem Inc., CMPC Tissue SA, Proterrgo Inc., Andritz AG | Enlighten Innovations Inc., Kara Technologies Inc., Sixring Inc., Field Upgrading Ltd., Expander Energy Inc. |
| **Top Jurisdictions** | US, CA, EP | US, CA, EP | CA, US, EP | US, CA, EP |
| **Top Categories** | Pyrolysis and Carbonization, Sorting and Scaling, Bucking | Anaerobic and Aerobic Digestion/Composting, Hydrolysis, Bio-Oil | Pyrolysis and Carbonization, Gasification, Hydrolysis | Pyrolysis and Carbonization, Gasification, Fermentation |

- Canada's forest bioeconomy companies seem to be majorly present in four provinces: British Columbia, Alberta, Ontario and Quebec. Ontario-based companies seem to have filed more patents than companies in other Canadian provinces.

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# British Columbia-based Inventors Patent Insights- Sustainable Bioprocessing and Value-added Products/Materials/Applications

| | British Columbia-based Inventors | Quebec-based Inventors | Ontario-based Inventors | Alberta-based Inventors |
|---|---|---|---|---|
| **Patent Families** | 32 | 34 | 67 | 18 |
| **Expanded Dataset** | 131 | 113 | 293 | 73 |
| **Granted Patents** | 86 | 70 | 158 | 34 |
| **Pending Applications** | 45 | 43 | 135 | 39 |
| **Top Assignees** | Suzano Canada Inc., Licella Pty Ltd., Canfor Pulp Ltd., Carboncure Technologies Inc. | CMPC Tissue SA, Andritz AG, Proterrgo Inc., Anomera Inc., Polystyvert Inc. | Iogen Corp., Norwood Ind Inc., Comet Biorefining Inc., Plascoenergy IP Holdings Sl, Calmwave Inc. | Kara Technologies Inc, Enerkem Inc, Sixring Inc, Occidental Petroleum Corporation |
| **Top Jurisdictions** | US, CA, EP | CA, US, EP | US, CA, EP | US, CA, EP |
| **Top Categories** | Pyrolysis and Carbonization, Sorting and Scaling, Bucking | Anaerobic and Aerobic Digestion/Composting, Hydrolysis, Bio-Oil | Pyrolysis and Carbonization, Gasification, Hydrolysis | Pyrolysis and Carbonization, Gasification, Fermentation |

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

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# British Columbia-based Market Insights

**This section highlights market trends, key players, investments, and policy impacts specific to British Columbia.**

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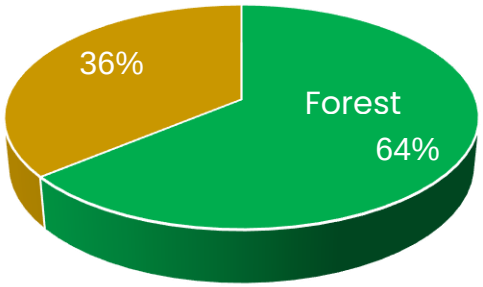
# British Columbia-based Market Insights (1/9)

**B.C.'s Land Distribution**




- 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. is identified as the **top province,** having the maximum number of **companies operating across** the value chain of the **forest bioeconomy.**
- B.C. **contributed $4.98 billion** in Canadian's real **GDP in 2021**.

95%

of B.C. forests are publicly owned

200M

seedlings planted annually

0.35%

of B.C. forests harvested yearly

44M

Hectares of certified forests in B.C.

35,644

Employment in sector in B.C.

(Source 1, Source 2)

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# British Columbia-based Market Insights (2/9)

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
- 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
- Western Forest Products — Defining a Higher Standard

## Value-added Products/Materials/ Applications

- Canadian AgriChar — Manufacturer & Distribution of Biochar
- BC Biocarbon
- Echo Tech Carbon Corp. — Solving for Co2-Climate Trend Setters
- Consolidated Biofuels
- reforus
- Greenlane
- Arbios Biotech
- Cariboo Low Carbon Fuels Ltd.
- Highbury Energy
- nexterra
- pcs Technology
- Quadrogen
- Bast Fibre Tech
- Arterran Renewables
- ABG 3D Bioform
- BIOBOOST
- Reforest Design
- Coastland Wood Industries Ltd.
- Fraser Wood residential 01922 627686
- Calmura Natural Walls
- StructureLam Mass Timber Corporation — Intelligence In Wood
- StructureCraft
- drax
- Seagate
- Tolko
- PowerWood

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# British Columbia-based Market Insights (3/9)

## 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 Technologies
- Hummingbird Drones
- Pinnacle Renewable Energy
- Tolko
- bid group
- Canfor
- andion
- COGEI
- Expander Energy Inc.
- IMG Industries Inc

## Investments

- BC Biocarbon
- Bioform
- Paper Excellence
- andion
- Bast Fibre Tech

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# British Columbia-based Market Insights (4/9)

**Major Investments Driving Growth**: Government and private sector funding for B.C.'s forestry industry.

| Investment | Amount | Purpose & Impact |
|---|---|---|
| **Federal Investment (March 2025)** | $20M | Funds 67 projects to boost competitiveness & resilience in B.C.'s forestry sector. (Source) |
| **Forestry Capital Projects (Sept 2024)** | $11.4M | Supports eight capital projects & one planning project across B.C. (Source) |
| **Advanced Wood Manufacturing (Kamloops)** | $20M | Tolko Industries' Heffley Creek expansion → New Engineered Wood Division. 250 jobs retained, 20 new created. (Source) |

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# British Columbia-based Market Insights (5/9)

**Key Forestry Policy Updates in B.C.**: Major government policies and initiatives shaping B.C.'s forestry sector.

| Date | Key Policy Development | Impact on B.C. |
|---|---|---|
| Feb 2023 | **Forest Carbon Offset Protocol 2.0 Released**– Updated framework for forest carbon projects. | Encourages sustainable forestry & emissions reduction. (Source) |
| 2025 & Beyond | **Softwood Lumber Advisory Council Formed**– Aims to tackle United States tariffs & advocate for B.C. forestry workers. | Works to eliminate **14.4% of United States tariffs**, ensuring fair trade & job security. (Source) |
| 2025 | **BC Timber Sales review-** Addresses challenges in the forestry sector, such as declining allowable annual cuts and difficulties in accessing fibre. | Promotes forestry sector growth, job creation, and sustainable management through market access, fibre diversification, and community partnerships. (Source) |

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# British Columbia-based Market Insights (6/9)

**Adapting to Market Shifts & Global Trends**: How industry players are responding to economic pressures and policy changes.

| Issue | Key Developments | Impact on B.C. |
|---|---|---|
| 📉 **B.C. Companies Expanding to United States** | Canfor, West Fraser, Interfor, and Teal-Jones are moving operations to **the United States South**. | Mill closures, job losses, reduced domestic production. (Source) |
| 🌎 **Foreign Investment in B.C. Timberland** | A **United States forestry investment fund** acquired **14,500 hectares** in B.C. | Concerns over resource ownership, sustainability, and control. (Source) |
| 🚧 **Softwood Lumber Trade Dispute** | The United States maintains **14.4% tariffs** on Canadian lumber; Canada challenges through the WTO & USMCA. | Export barriers, reduced revenues, increased competition. (Source) |

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# British Columbia-based Market Insights (7/9)

**Research centers and Innovation Institutions in B.C.**

| Institutions | Description |
|---|---|
| University of British Columbia | • The Centre for Advanced Wood Processing specializes in research on wood product processing and advanced manufacturing.<br>• The Centre of Interactive Research on Sustainability explores sustainable building materials and design.<br>• The Pulp and Paper Centre is a multi-disciplinary research hub with dedicated laboratories and offices supporting pulp and paper industry advancements.<br>• The UBC Faculty of Forestry is recognized as Canada's top forestry school. |
| University of Northern British Columbia | • The Northern Forest Products and Bioenergy Innovation Centre conducts comprehensive research on bioenergy, covering technology, policy, and health aspects.<br>• The Wood Innovation and Design Centre offers a Master of Engineering in Integrated Wood Design, addressing the growing demand for engineered wood products, tall timber structures, and sustainable construction.<br>• The Enhanced Forestry Laboratory facilitates controlled environment research and education. |
| British Columbia Institute of Technology | • The Building Science Centre of Excellence at BCIT's School of Construction and the Environment specializes in new building design, advanced materials, and building envelope research.<br>• BCIT also offers technical trades training and degree programs to support the construction and industry sectors. |
| Okanagan College | • The Jim Pattison Centre of Excellence in Sustainable Building Technologies provides courses in sustainable construction management technology, green building design and construction, and building envelope construction. |

(Source 1)

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# British Columbia-based Market Insights (8/9)

**Support Programs in B.C. for the forestry sector:**

| Program | Description |
|---|---|
| Indigenous Forest Bioeconomy Program (IFBP) | Provides funding and support to Indigenous project partners that helps to maximize the use of forest biomass by making bioproducts. |
| BC Bioenergy Network | Promotes bioenergy development and commercialization in British Columbia. Funds research, technology advancements, and pilot projects to enhance renewable energy solutions from forest biomass and waste materials. |
| Investments in Forest Industry Transformation Program | Supports the development of innovative technologies that enable the production of high-value, non-traditional forest products and renewable energy solutions. |
| Forestry Innovation Investment | Collaborates with trade associations, research institutions, and government agencies to sustain current markets for B.C. forest products and expand into new markets. In addition to market development and research support. It implements various marketing initiatives but does not offer loans, subsidies, or direct financial incentives to individual businesses. |
| BC Community Forest Association (BCCFA) | Supports community forest initiatives that practice ecologically responsible forest management in B.C, fostering healthy and vibrant rural communities and economies. |
| Forest Enhancement Society of BC (FESBC) | Funds projects that reduce wildfire risk, enhance forest fibre utilization, and support ecosystem restoration. |

(Source 1, Source 2, Source 3)

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# British Columbia-based Market Insights (9/9)

**Industry And Trade Associations In B.C**.: Globally recognized forest-products research network that supports the British Columbia's forest sector through advocacy, market development, research, and innovation -

| |
|---|
| APA — The Engineered Wood Association |
| BC Wood |
| BC Log and Timber Building Association |
| Forest Products Association of Canada |
| Interior Lumber Manufacturers' Association |
| Canada Wood Group |
| Canadian Wood Council |
| WoodWORKS! BC |
| Cedar Shake and Shingle Bureau |
| Council of Forest Industries |
| Independent Wood Processors Association of BC |
| Western Red Cedar Lumber Association |
| Wood Pellet Association of Canada |
| FPInnovations |
| Softwood Lumber Board |

(Source 1, Source 2)

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# Conclusions & Recommendations Technology Whitespaces Actionable Insights – Potential Risks and Opportunities

This section includes meaningful insights, strategic guidance, technology whitespaces, and potential risks and opportunities. It highlights innovation gaps, market challenges, and growth prospects to support informed decision-making.

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# Technology Whitespaces

**This section highlights opportunity areas, having low patenting activities with good future potential, therefore, can be considered for further research.**

The indicators—**High**, **Medium**, and **Low**—are assessed across three key aspects: Patent Activity, Products & Services, and Market Scope.

A **High** rating in patent activity indicates frequent filings and strong innovation, while **Medium** suggests steady activity and **Low** reflects limited R&D or a mature market.

For Products & Services, **High** points to diverse offerings and active competition, **Medium** implies moderate presence, and **Low** indicates a niche or emerging segment.

In terms of Market Scope, a **High** rating denotes a large and growing market with strong demand, **Medium** reflects stability or moderate growth, and **Low** suggests limited or declining interest.

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# Technology Whitespaces

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

The following areas are recommended as technology whitespaces in this domain:

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

| | | |
|---|---|---|
| PATENTED<br>**Patent Activity** | **Low** | • There seem to be a significant number of patent applications disclosing implementation of artificial intelligence in other areas. However, the use of such techniques in forestry tools and machinery seems to be less explored. Exemplary patents – CN113989641A and CN208348856U. |
| AI<br>**Products & Services** | **Medium** | • There are multiple research papers disclosing the use of AI-enabled machines for forestry operations.<br>• Swedish scientists have designed the world's first unmanned machine for autonomous forestry operations (Source). |
| **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. (Source). |

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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 the spread of wildfire in real time.


**Patent Activity**

**Low**

- There seem to be a significant number of patent applications disclosing implementation of digital twinning in other areas, e.g., manufacturing, industries, etc. . However, implementation of digital twinning in forests seem to be less explored. Few non-US patents disclose a 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 helped 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 the use of digital twins in forest management will also have a similar growth rate in the 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.

| | | |
|---|---|---|
| PATENTED<br>**Patent Activity** | **Low** | • There seems to be less filing in these two sustainable processing techniques. The Supercritical water gasification technique has only 14 patents, whereas Hydrothermal Liquefaction has around 150+ patents, compared to other Bioprocessing Techniques, such as Fermentation, Hydrolysis and Pyrolysis etc.<br>• 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 is 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 a CAGR of 14.0% by 2031. (Source). It is expected that the use of these techniques will also have a similar growth rate in the future. |

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# Actionable Insights

**This section highlights meaningful insights on emerging opportunities, potential risks, and strategic directions to drive informed decision-making and market growth.**

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# Actionable Insights – Potential Risks and Opportunities

Based on the patent landscape study and market study, potential risks and opportunities have been recommended for Canadian companies:

- **Potential Opportunities** – These include recommendations on what actions can be taken by Canadian companies to strengthen their position in terms of the 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 Canadian companies might face if proper measures are not taken at the right time.

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# Actionable Insights – Potential Opportunities

## IP Protection

### INSIGHTS

- The 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 a **competitive edge** in the 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** are emerging globally with innovative solutions in the forest bioeconomy, including biomass utilization and bio-based materials.
- Patent **filings by Canadian companies in related areas such as forest monitoring indicate growing interest and potential for strategic collaborations.**

### 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 the University of Toronto, the 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

- **Canadian patent filings are increasing year over year**, particularly in areas such as tree growth enhancement, pulp and paper processing techniques, and biofuels.
- 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 the 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 the key categories such as **wildfire management, forest monitoring, bioprocessing, etc., are present.**

### PREVENTIVE MEASURES

- Perform **due diligence** before entering other countries.
- **Use a different strategy for each country** based on their patent laws and presence 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

- No major patent litigations are recorded directly in the forest sector, but **related domains like bioprocessing and biomedical show active enforcement over bio-based innovations.**
- This suggests the **forest bioeconomy might see more patent litigations** in the future.

### PREVENTIVE MEASURES

- **Obtain patent licenses** for relevant products to prevent infringement risks.
- Build a **defensive patent portfolio.**

### POTENTIAL RISKS

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

**Actionable Insights – Potential Risks**

## Competitive Market

### INSIGHTS

- **The forest bioeconomy is growing fast,** with startups worldwide working **on sustainable materials, forest tech, and bio-based products.**

### PREVENTIVE MEASURES

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

### POTENTIAL RISKS

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

## Adapting New Technologies

### INSIGHTS

- The **forest bioeconomy is adopting AI, blockchain, and digital twinning** to improve management and traceability.

### 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 the 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

FORESIGHT

UnitedLex

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# Appendix A - Taxonomy Definitions (1/19)

| 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. |

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# Appendix A - Taxonomy Definitions (2/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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 of different natural hazards like wildfires, storms, landslides/earthquakes, hydrological events (droughts and floods), and insect/disease outbreaks. |
| 1.1.4.1.1 | Wildfire | Forest or wildfire detection involves real-time alerts/warning information and tracking/monitoring of large fires and related activities for timely prevention and control of forest fires. |
| 1.1.4.1.2 | Storms | Detecting forest storms involves predicting early storm alerts/warnings 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 (droughts or floods) involves drought or flood predictions along with real-time monitoring of hydrological events to mitigate the impacts on forest ecosystems. |
| 1.1.4.1.5 | Insect/Diseases Outbreak | Detecting insect/disease outbreak involves monitoring the forest ecosystem health in real-time to detect and/or predict any insect/disease 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 ecosystems. |
| 1.1.4.2.1 | Real-time Natural Hazards Monitoring | The real time natural hazards monitoring involves real-time data along with alerts/warnings related to the natural hazards impacting the forests. |
| 1.1.4.2.2 | Predicting Natural Hazards | 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. |

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# Appendix A - Taxonomy Definitions (3/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 1.2.3 | LiDAR | LiDAR sensors equipped with drones or ground/aerial vehicles for generating 3D maps and models of the forest areas, allowing for detailed analysis of the 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. |

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# Appendix A - Taxonomy Definitions (4/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (5/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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 | Directional Felling and Sectional Dismantling | Directional 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. |

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# Appendix A - Taxonomy Definitions (6/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (7/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (8/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |

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# Appendix A - Taxonomy Definitions (9/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (10/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 2.2.2.2 | Chipping or Grinding | Process involves the chipping or grounding the sorted wood residue or forest waste into smaller pieces to increase the surface area of the material, making it easier to process. |
| 2.2.2.3 | Pulping | Process of separating fibres 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 fibres 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 fibres from wood or other biomass materials. |
| 2.2.2.4 | Bleaching | The process of removing 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 fibres 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 fibres to form a wet paper sheet, and then passing the wet paper sheet through heated drying cylinders to evaporate the remaining moisture, results in a dry paper sheet ready for finishing. |
| 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 is used in saw-mills for cutting, sawing, and processing timber. |

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# Appendix A - Taxonomy Definitions (11/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| **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 and 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 the outer bark layer via mechanical or biochemical means 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 involves 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 and excess material and creating straight edges on the lumber obtained after cutting the logs. |
| **2.3.2.6** | **Planing, Moulding and Profiling** | The process involves smoothening the surfaces, achieving uniform thickness, and processing the lumber through moulders or profiling machines to add decorative or functional profiles. |

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# Appendix A - Taxonomy Definitions (12/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 2.3.2.7 | Drying | The process of drying lumber 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. |
| 3 | Value-added Products/Materials/Applications | After processing 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 fibres 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 fibres bonded together with resin under heat and pressure. |

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# Appendix A - Taxonomy Definitions (13/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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 Fibreboard (MDF) | A type of engineered wood product made from wood fibres 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 Fibreglass | Composite material made from wood fibres and fibreglass, 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. |

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# Appendix A - Taxonomy Definitions (14/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (15/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 3.4.1 | Wood-based Biomaterials | Biomaterials derived from wood or wood fibres, such as cellulose nanocrystals, lignin-based polymers, or wood composites. |
| 3.4.1.1 | Wood Fibre | 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 fibres, 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (16/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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, fibres, or materials used for clothing, furnishings, or industrial applications, made from natural or synthetic fibres, including biomaterials or bio-based fibres. |
| 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. |

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# Appendix A - Taxonomy Definitions (17/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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. |
| 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 fibres, 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. |

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# Appendix A - Taxonomy Definitions (18/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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, fibres, 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. |
| 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. |

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# Appendix A - Taxonomy Definitions (19/19)

| S. No. | Taxonomy Nodes | Definition |
|---|---|---|
| 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 the 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 – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| 3F Waste Recovery | Bioprocessing | Bast Fiber Tech | Biomaterials/Bioproducts |
| 4pi Lab Inc. | Forest Management | BC Biocarbon | Biochar & Solid Carbon |
| Advanced Biocarbon 3D (ABC3D) | Biomaterials/Bioproducts | Bella Biochar Corporation | Biochar & Solid Carbon |
| AE Côte-Nord Canada Bioenergy Inc. | Biofuel & Biogas Processing | Benemat Scientific Inc. | Bioprocessing |
| AecopaQ | Biomaterials/Bioproducts | Bioboost Synbio | Biomaterials/Bioproducts |
| Airex Energy | Biochar & Solid Carbon | BioDiffusion Technologies | Biomaterials/Bioproducts |
| Al-Pack Enterprises | Biomaterials/Bioproducts | Bioenergy Solutions Inc | Biochar & Solid Carbon |
| Alberta Pacific Forest Products Inc. | Pulp & Paper Mills | BioForest | Forest Replanting & Silviculture |
| ALC Bio Innovations Inc. | Bioprocessing | Bioform Technologies | Biomaterials/Bioproducts |
| Anaergia Inc. | Bioprocessing | Biomass Energy Techniques | Biochar & Solid Carbon |
| Andion Group | Bioprocessing | Biopolynet | Bioprocessing |
| Anomera | Bioprocessing | Blue Goose Biorefineries | Bioprocessing |
| Arbec Forest Products | Engineered Wood Products | Boralife | Value added Manufacturing |
| Arbios Biotech | Biofuel & Biogas Processing | Bosk Bioproducts | Biomaterials/Bioproducts |
| Art Massif | Engineered Wood Products | BP Canada | Engineered Wood Products |
| Arterran Renewables | Biofuels | Braya | Biofuel & Biogas Processing |

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# Appendix C – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| BryoSphere Biotechnologies | Bioprocessing | CH Four Biogas | Biofuel & Biogas Processing |
| Calmura Natural Walls | Engineered Wood Products | Char Technologies | Biochar & Solid Carbon |
| Canadian Agrichar | Biochar & Solid Carbon | Charterra | Biochar & Solid Carbon |
| Canary Biofuels | Biofuel & Biogas Processing | Chembiopower | Bioprocessing |
| Canfor | Saw & Lumber Mills | ClimaTech Innovations Inc. | Forest Replanting & Silviculture |
| Carbon Lock Technologies | Biochar & Solid Carbon | Climicals | Bioprocessing |
| Carbon OxyTech Inc. | Bioprocessing | Coastland Wood Industries Ltd. | Engineered Wood Products |
| Carbonface | Biochar & Solid Carbon | Comet Biorefining | Bioprocessing |
| Cariboo Low Carbon Fuels Ltd. | Biofuel & Biogas Processing | Commercial Bioenergy Inc. | Biomass Heat & Power Generation |
| Carrier Lumber | Saw & Lumber Mills | Conifex Timber | Saw & Lumber Mills |
| Cascades | Biomaterials/Bioproducts | Consolidated biofuels | Biofuel & Biogas Processing |
| Celluforce | Bioprocessing | Coopérative forestière Ferland-Boilleau | Harvesting Operations |
| Cellufuel | Biofuel & Biogas Processing | CRB Innovations | Biofuel & Biogas Processing |
| Cellulotech | Bioprocessing | Creatus Biosciences | Bioprocessing |

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# Appendix C – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| Cvictus Inc. | Biofuel & Biogas Processing | Ensyn | Biofuel & Biogas Processing |
| Dispersa Inc. | Bioprocessing | Evoco | Biomaterials/Bioproducts |
| Drax Group Canada - Pinnacle Renewable Energy Group | Wood Pellets | Expander Energy Inc. | Biofuel & Biogas Processing |
| Drystill Holdings Inc. | Bioprocessing | FireRein | Biochemicals |
| Dunkley Lumber Ltd. | Saw & Lumber Mills | FITEC Environmental Technologies Inc. | Biofuel & Biogas Processing |
| Eacom | Value Added Manufacturing | FITNIR Analyzers | Pulp & Paper Mills |
| Echo Tech Carbon | Biochar & Solid Carbon | Flash Forest | Forest Management |
| Ecopackers | Biomaterials/Bioproducts | Fluid Energy Group | Biochemicals |
| Ecostrat | Harvesting Operations | Forge Hydrocarbons | Biofuel & Biogas Processing |
| EcoSynthetix | Bioprocessing | Fortress Advanced Bioproducts | Bioprocessing |
| Element5 | Engineered Wood Products | Fraser Wood | Engineered Wood Products |
| Energir | Biofuel & Biogas Processing | FTS Forest Tech | Forest Management |
| Enerkem | Biofuel & Biogas Processing | Fulcrum Energy Corporation | Pyrolysis & Carbonization |
| Enerkem Inc. | Biochemicals | Future Bioenergy Solutions Inc. - Fubisol | Bioprocessing |

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# Appendix C – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| Fybr | Saw & Lumber Mills | Interfor | Saw & Lumber Mills |
| Goodlam | Engineered Wood Products | Iogen | Biofuel & Biogas Processing |
| Granules LG | Wood Pellets | Kalesnikoff | Saw & Lumber Mills |
| Greenlane Renewables Inc. | Biofuel & Biogas Processing | KAM Biotechnology Ltd. | Bioprocessing |
| Greenlid Environsciences | Biomaterials/Bioproducts | Kruger Inc. | Value Added Manufacturing |
| Harmac | Pulp & Paper Mills | LGD | Biochemicals |
| Hermay Labs | Bioprocessing | Lily Plain Biochar | Biochar & Solid Carbon |
| Highbury Energy Inc. | Biofuel & Biogas Processing | Meadow Lake Tribal Council's (MLTC) bioenergy plant | Biomass Heat & Power Generation |
| Hummingbird Drones | Forest Management | Mercer | Pulp & Paper Mills |
| HY2GEN Canada Inc. | Biofuel & Biogas Processing | Milltech | Saw & Lumber Mills |
| Ineos | Bioprocessing | Molten Arbour | Biomass Heat & Power Generation |
| Innoltek | Biofuel & Biogas Processing | Mosaic Forest Management | Harvesting Operations |
| Innonet Inc. | Bioprocessing | MSL | Engineered Wood Products |
| Innovative Reduction Strategies Inc. (IRSI) | Pyrolysis & Carbonization | Nanostech | Biofuel & Biogas Processing |

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# Appendix C – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| NanoTerraTech | Bioprocessing | Project Forest | Forest Replanting & Silviculture |
| Nexterra Systems Corp. | Biofuel & Biogas Processing | Pure Life Carbon | Biochar & Solid Carbon |
| NextStep Renewable Energy Inc. | Biofuel & Biogas Processing | Pyrovac | Pyrolysis & Carbonization |
| Nfinite Nanotech | Bioprocessing | Quadrogen | Biofuel & Biogas Processing |
| Nordic Structures | Engineered Wood Products | Rainforest Energy | Biofuel & Biogas Processing |
| NorthPac Forestry Group Ltd. | Harvesting Operations | RAW Biochem | Biochemicals |
| NovEnviro Inc. | Engineered Wood Products | Reforest Design | Engineered Wood Products |
| NULIFE GreenTech Inc. | Bioprocessing | Reforus | Biochemicals |
| Origin Materials | Bioprocessing | Remsoft | Harvesting Operations |
| Ozonebio | Bioprocessing | Rhyme Biotechnology | Bioprocessing |
| Paper Excellence | Pulp & Paper Mills | San Group | Saw & Lumber Mills |
| PCS Technologies | Biofuel & Biogas Processing | SBI Bioenergy | Biofuel & Biogas Processing |
| Performance Biofilaments | Bioprocessing | Seagate | Engineered Wood Products |
| Plantee Bioplastics | Bioprocessing | Shaw Resources | Wood Pellets |

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# Appendix C – Canadian Startups' List

| Company | Industry | Company | Industry |
|---|---|---|---|
| Silvacom Fms | Harvesting Operations | Tree Track Intelligence | Forest management |
| Sinclar Group | Saw & Lumber Mills | TreeCycle Environmental Inc. | Saw & lumber mills |
| Sixring Inc. | Bioprocessing | Treeera | Forest replanting & silviculture |
| Steeper Energy | Biofuel & Biogas Processing | Viridis Terra | Forest replanting & silviculture |
| StructureCraft Builders Inc. | Engineered Wood Products | Vyterra Renewables | Biofuel & biogas processing |
| Structurlam-to be purchased by Mercer | Engineered Wood Products | West Fraser | Saw & lumber mills |
| Suncor Energy | Biofuel & Biogas Processing | Western Archib | Engineered wood products |
| Teal Jones | Saw & Lumber Mills | Western Forest Products | Saw & lumber mills |
| Terra optima labs | Biochar & Solid Carbon | Wild and Pine | Forest management |
| TerraVerdae Bioworks Inc. | Bioprocessing | Wildfire Innovations | Forest replanting & silviculture |
| Tidewater renewables | Biofuel & Biogas Processing | Woodland Biofuels | Biofuel & biogas processing |
| Timmerman Timberworks | Engineered Wood Products | Zanzibar Holdings Ltd. | Forest replanting & silviculture |
| Titan Carbon Smart Technologies | Biochar & Solid Carbon | Zen Earth Corp. | Biochemicals |
| Tolko | Value Added Manufacturing | Tree Track Intelligence | Forest management |

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# Appendix D – Key Government Policies and Initiatives

This section includes regulations, funding programs, and strategic initiatives influencing industry growth, innovation, and market dynamics.

FORESIGHT UnitedLex

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# Appendix D - Key Canadian Government Policies and Initiatives (1/2)

Canada accounts for only ~0.3% of global deforestation. The Canadian government seems to be actively taking initiatives to improve forest management in Canada. Below are a 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** – The 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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# Appendix D - Key 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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# Appendix D - Key Global Policies and Initiatives (1/2)

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

- **In the United States, the 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 members of ITTO are Brazil, the USA, Canada, and China. (Source)
- **The Food and Agriculture Organization of the United Nations** helps the United Nations member countries to **overcome the constraints to sustainable forest management by providing information and policy advice**. FAO helps countries define the elements of Sustainable Forest Management in their national contexts and 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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# Appendix D – Key Global Policies and Initiatives (2/2)

- The **Sustainable Forestry Initiative (SFI)** unveiled its SFI 2025-2030 Strategic Direction at the 2024 SFI Annual Conference, deepening its commitment and setting a vision for a world that values and benefits from sustainably managed forests. SFI will develop and promote standards that provide an assurance of sustainable forestry and responsible sourcing of forest products. (Source)

- Environment ministers of the Group of 20 nations agreed Thursday to support the creation of funding sources for ecosystem services, acknowledging **Brazil's proposal to establish a trust fund for forest conservation**. (Source)

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# Appendix D - Appendix E - 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.
- Patent publications that disclose similar concepts in agricultural or farm fields may not be applicable to forest land.
- Patent publications that generically disclose the use of drones, satellites, etc. to map or monitor geographic areas but do not disclose applicability in the 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 resins, adhesives, etc.), perfuming compositions comprising biomaterials, etc.

**Assumptions**

- The number of patents/ published applications filed in 2023/2024/2025 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 the 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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