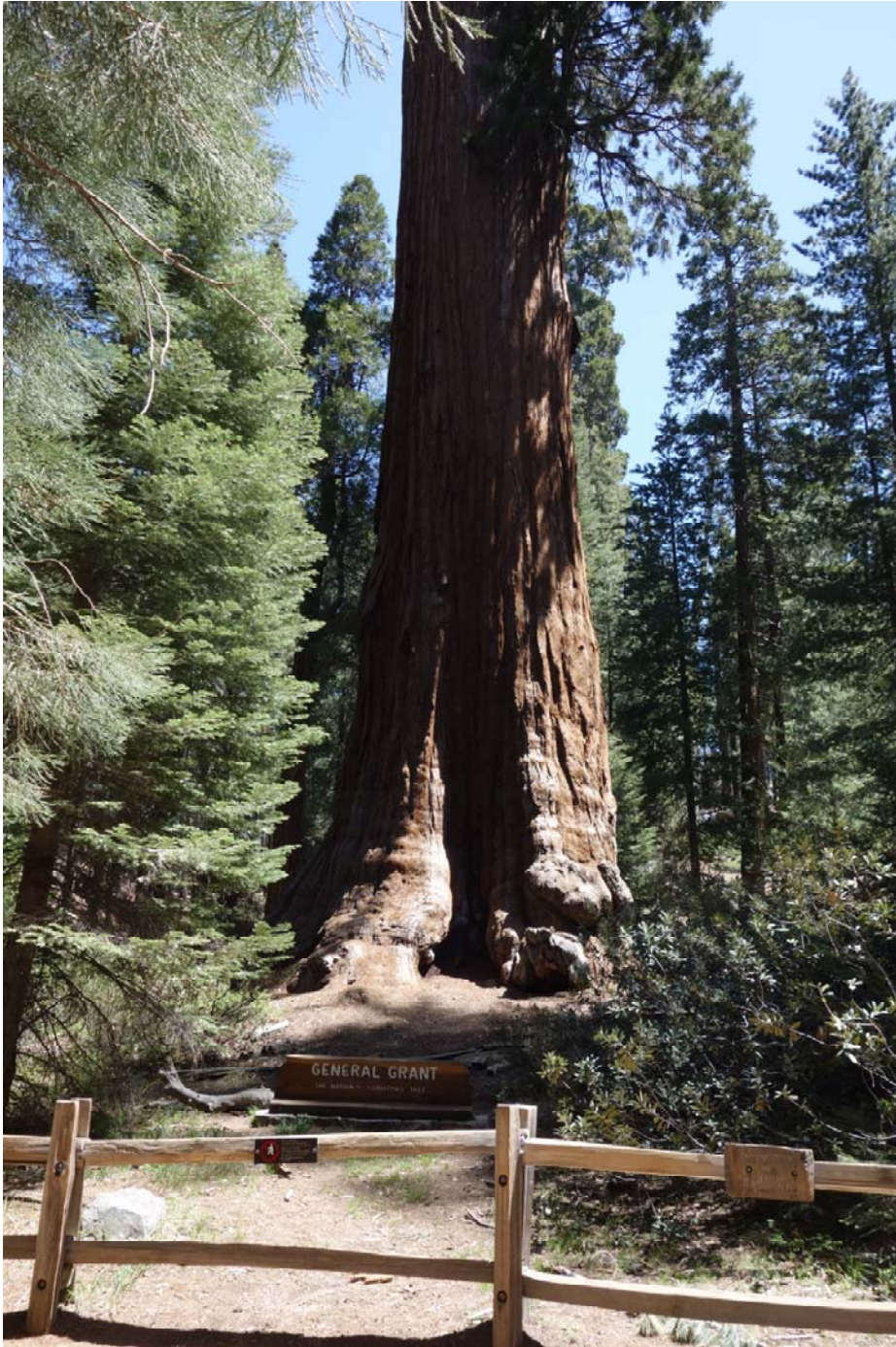


Lignin 2021

A pivotal year

By Jack Miller

**BioBased
Markets**



On the cover:

The General Grant Tree, a giant sequoia in California's Kings Canyon National Park, is one of the largest trees in the world. It stands 267 feet tall, and lignin makes this possible

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Table of Contents

1. Acknowledgments.....	12
2. Introduction, Methodology, and Scope	13
Methodology	15
Scope	18
Notes.....	18
3. Executive Summary	19
4. Introduction to Lignin.....	24
Lignin Processes	28
5. Lignosulfonate.....	31
5.1 LignoTech	33
5.2 Pulp and Paper Mills	36
5.3 Sulfonated kraft lignin.....	38
6. Kraft Lignin.....	39
6.1 LignoBoost®	42
6.2 LignoForce System™	45
6.3 ValChem	48
6.4 Sequential Liquid Lignin Recovery and Purification	49
6.5 A-Recovery+	52
7. Biorefinery Lignin	53
7.1 PROESA®.....	57
7.2 sunliquid®	60
7.3 SWEETWOODS.....	63

7.4	Sunburst™ Reactive Extrusion	66
7.5	MetGen ENZINE® Enzyme Platform.....	69
7.6	Praj enfinity™	73
7.7	AVAP® and Green Power+®	75
7.8	Leuna.....	78
7.9	TMP-Bio.....	80
7.10	Sekab CelluAPP®	81
7.11	CH-Bioforce Pressurized Hot Water Extraction.....	83
7.12	Organosolv	85
7.13	Supercritical water.....	88
7.14	Inbicon high pressure steam	89
7.15	EvoLUTIA™.....	90
7.16	Soda Lignin	91
7.17	Other biorefinery processes.....	92
8.	2021: The State of the Industry	96
8.1	Covid Impact.....	98
8.2	PESTEL Analysis.....	101
8.3	Lignosulfonate	105
8.4	Kraft lignin	108
8.5	Biorefinery Lignin.....	111
9.	Forecast	116
9.1	Base Case.....	117
9.2	Conservative Forecast.....	120

9.3	Optimistic Forecast	121
10.	Valorization	122
10.1	Aromatics	123
10.2	Depolymerization	125
10.3	Lignin Biocomposites	130
10.4	Vanillin, carbon fiber and other high-value materials	131
10.5	Conclusion	132
11.	Markets and Applications	133
11.1	Activated carbon.....	135
11.2	Vanillin.....	136
11.3	Carbon fiber.....	137
11.4	Phenol, phenolic resins	139
11.5	Benzene, Toluene, and Xylene (BTX)	142
11.6	Cement/concrete additives.....	145
11.7	Biofuels.....	146
11.8	Bitumen and Asphalt	148
11.9	Dispersants and binders.....	150
11.10	All other.....	151
11.10.1	Batteries.....	151
11.10.2	Biocomposites	152
11.10.3	Brake Pads.....	153
11.10.4	Carbon Black.....	153
11.10.5	Graphene	153

11.10.6 Nanocellulose	154
11.10.7 Oil and gas	154
11.10.8 Paints and coatings	155
11.10.9 Rubber.....	156
12. Profiles.....	157
Abengoa.....	157
Aditya Birla Group	157
Aemetis.....	158
American Process, Inc.	158
American Science and Technology	159
Andritz AG.....	160
Anellotech.....	161
Avantium N.V.	162
BBI JU.....	163
Beta Renewables.....	164
Biochemtex	164
Blue BioFuels, Inc.	164
The Borregaard Group.....	165
Burgo Group S.p.A.....	166
CellMark AB	167
CH-Bioforce OY.....	167
Chempolis Oy	168
Chemtex Global Corporation	169

CIMV	170
Clariant AG	171
CMPC	172
Domsjö Fabriker AB.....	172
Domtar Inc.	173
Energochemica SE	174
Enerkem.....	175
Eni S.p.A.	176
Enviral a.s.....	177
Fibria Celulose S.A.	177
FP Innovations.....	178
Futurity Bio-Ventures Ltd.	179
G+E GETEC Holding GmbH.....	180
Glydia Biotech LLC.....	181
Graanul Biotech	181
GranBio Technologies.....	182
Hexion Inc.	184
INEOS Group Holdings S.A.	185
Ingevity	186
logen Corporation	187
Klabi S.A.	188
Leaf Resources Ltd.	189
LignolProduktion AB.....	190

Lignum, Inc.....	190
Liquid Lignin Company	191
LXP Group GmbH	192
MetGen Oy.....	192
NewEnergyBlue LLC.....	194
Nippon Paper Industries Co. Ltd.	195
NordFuel Oy	196
Ørsted A/S.....	197
POET LLC	197
Praj Industries Ltd.	198
PRISMA Renewable Composites.....	199
Pure Lignin Environmental Technology, Ltd.	200
Raízen	201
Rayonier Advanced Materials.....	202
Ren Com AB	203
RenFuel AB.....	203
Renmatix.....	204
Resolute Forest Products, Inc.	205
RISE Research Institutes of Sweden AB.....	206
Sainc Energy	207
Sappi Limited	208
Shengquan Group	209
Stora Enso Oyj.....	209

Suzano S.A.....	211
Svensk Etanol Kemi AB	212
Sweetwater Energy	213
SWEETWOODS Project	215
Tembec, Inc.....	216
UPM Biochemicals.....	216
Valmet Oyj	217
VERBIO North America Corporation	218
Versalis S.p.A.....	219
Vertoro	220
West Fraser Timber Co. Ltd.	221
Wuhan East China Chemical Company, Ltd.....	222
Xingzhenghe Chemical Co., Ltd.....	223
13. Bibliography	224
14. Glossary	226

List of Tables

2.1	Megatrends Impacting Lignin Markets.....	14
3.1	Volume by Segment, 2020.....	19
3.2	Base Case Forecast.....	21
3.3	Lignin Applications Potential Value.....	22
4.1	Lignin Content in Biomass.....	26
4.2	Volume by Segment, 2020.....	28
5.1	Lignosulfonate Patents.....	32
5.2	Borregaard Lignotech Locations.....	33
5.3	Lignotech Patents.....	35
6.1	LignoBoost® Installations.....	42
6.2	LignoBoost® Patents.....	44
6.3	LignoForce System™ Patents.....	46
6.4	SLRP Patent Filings.....	50
7.1	Key Patents related to PROESA® Process.....	58
7.2	sunliquid® Installations.....	60
7.3	SWEETWOODS Consortium Partners.....	63
7.4	Key Patents Related to Sweetwater Sunburst Process.....	66
7.5	U.S. Patents Related to MetGen Lignolytic Enzymes.....	71
7.6	GranBio Biorefinery Platform Patents.....	75
8.1	Volume by Segment 2020.....	96
8.2	BBI JU Funded Lignin-related Projects.....	102
8.3	Lignosulfonate Supply 2020.....	105
8.4	Kraft Lignin Capacity.....	108
8.5	Equivalency of 1 million gallons of ethanol.....	113
8.6	Second Generation Biorefineries.....	114
9.1	Base Case Forecast.....	117
9.2	Conservative Forecast.....	120
9.3	Optimistic Forecast.....	121
11.1	Current and Potential Lignin Applications.....	133
11.2	Lignin Applications Potential Value.....	134

List of Figures

4.1	Lignin.....	24
4.2	Phenyl Monomers in Lignin.....	25
4.3	Dried Lignin.....	25
6.1	Method of Producing Lignin from Black Liquor.....	40
6.2	LignoBoost® Process.....	43
6.3	LignoForce™ System.....	45
6.4	Lignin Depolymerization Process.....	47
6.5	ValChem Project.....	48
6.6	SLRP™ Process.....	49
7.1	PROESA® Process.....	57
7.2	sunliquid® Process.....	61
7.3	SWEETWOODS Project.....	64
7.4	Sweetwater Energy Reactive Extrusion.....	67
7.5	Optimization of Enzyme Cost.....	69
7.6	Biorefinery Optimization.....	70
7.7	Enfinity™ “Bolt-on” Pretreatment and Hydrolysis.....	73
7.8	AVAP Process.....	77
7.9	Leuna Biorefinery.....	78
7.10	CelluAPP® Biorefinery Platform.....	81
7.11	CH Bioforce Pressurized Hot Water Extraction.....	83
7.12	CTS 2.9 Mechanocatalytic Process.....	93
8.1	Crude Oil Prices.....	99
10.1	Lignin Valorization.....	123
10.2	Phenol.....	124
10.3	Solid Liquid Extraction.....	126
10.4	Lignin Depolymerization Adds Value.....	128
11.1	Benzene, Toluene and Xylene (BTX).....	142
11.2	BioTCat™	144

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- Dr. Hasan Jameel, Jordan Family Distinguished Professor, Department of Forest Biomaterials, North Carolina State University
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- Dr. Michael Paleologou, Senior Scientist, FPInnovations, Chemical Process Group
- Dr. Orlando Rojas, Professor and Canada Excellence Research Chair, University of British Columbia, and Scientific Director Bioproducts Institute

Jack Miller
Biobased Markets
March, 2021

2. Introduction, Methodology, and Scope

A golfer might tell you that trees are 90% air. They'll say this as you are about to hit a shot with a tree in the way, and of course, they're joking. We know that trees, and other plants, are composed of cellulose, hemicellulose, and lignin. In trees, cellulose is typically around 45% of the dry mass, hemicellulose 25%, and lignin 25%, though this varies depending on the species, with lignin content ranging from 15% to 40%.^{1, 2}

Cellulose is a complex carbohydrate polymer composed of glucose molecules, while hemicelluloses are shorter-chain carbohydrates that primarily include C5 sugars such as xylose, and some C6 sugars such as glucose. Lignin is a complex aromatic macromolecule that is essentially the “glue” that holds the cellulose and hemicellulose fibers together.

Nature produces approximately 20 billion tonnes of lignin each year,^{3, 4} but historically, lignin was the undesirable part of the biomass. Most lignin has long been derived as a by-product in pulp and paper production. In a pulp mill, wood chips are broken down with heat and chemicals in a

In five or ten years, when we look back, we likely will see that 2021 was a pivotal year for lignin.

digester, removing most of the lignin and hemicellulose and creating a pulp primarily composed of strong cellulose fibers. The pulp then goes to the paper mill to produce brown kraft⁵ paper for

¹ Miller J. Lignin: Technology, Applications and Markets, RISI, 2017.

² Novaes E. et al. *Lignin and Biomass: A Negative Correlation for Wood Formation and Lignin Content in Trees*; Plant Physiology, Oct. 6, 2010. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2949025/>

³ Dessbesell L. et al. Global lignin supply overview and kraft lignin potential as an alternative for petroleum-based polymers. Renewable and Sustainable Energy Reviews, Volume 123, 2020, 109768, ISSN 1364-0321, <https://doi.org/10.1016/j.rser.2020.109768>.

⁴ Smolarski N. High-value opportunities for lignin: unlocking its potential. Frost and Sullivan, 2012. <https://www.greenmaterials.fr/wp-content/uploads/2013/01/High-value-Opportunities-for-Lignin-Unlocking-its-Potential-Market-Insights.pdf>

⁵ Kraft is the German word for “strong”

grocery bags or containerboard for corrugated boxes. These products are brown because some of the residual lignin remains in the pulp. To produce white paper, the pulp is bleached to remove the remaining lignin.

Table 2.1
Megatrends Impacting Lignin Markets
Sustainability: circular bioeconomy legislative: biofuel mandates utilize waste biomass stronger, lighter materials > material reductions better gas mileage less reliance on oil-based products don't compete with food
Economic: use cheaper feedstocks, i.e., agricultural residues stronger, lighter materials > less material, lower cost use the entire biomass optimize all value streams
Source: Biobased Markets

Today several megatrends have combined to drive interest in lignin (Table 2.1), and 2021 may well be a pivotal year for development of lignin-based products and markets. As biorefineries emerged to produce cellulosic ethanol, they originally used corn. Concerns about fuel competing with food gave rise to second generation (2G) biorefineries that produce ethanol from agricultural residues such as corn stover, but many of these biorefineries failed. While the process worked, the economics did not. Now we are seeing a new generation of biorefineries that seek to optimize the full value stream: cellulose for specialty cellulose, nanocellulose and biocomposites; ethanol from cellulose and C6 sugars; chemical building blocks and bioplastics from C5 sugars; lignin and value-added lignin derivatives.

At the same time, pulp and paper mills are embracing the concept of the circular economy, and are also seeking value-added product streams as paper markets decline: nanocellulose and cellulose specialties, and of course, lignin.

The objective of this report is to explore the growing interest in lignin from the converging worlds of biorefineries and pulp mills and their customers, to examine the different forms of lignin, and to review the state of the industry and provide and forecast to 2030. This report covers the various forms of lignin, including lignosulfonate, kraft lignin, and a range of biorefinery lignins, and includes profiles of more than 70 mills, biorefineries, and technology providers.

Methodology

This report was written by Jack Miller, Founder and Principal Consultant, Biobased Markets, a unit of Market-Intell LLC. Jack has more than thirty years' experience in market research and marketing strategy related to paper and paperboard. Since 2009, his focus has been on markets for bio-based products such as nanocellulose, biocomposites, and lignin.

He is a member of the Advisory Board of Sweetwater Energy, a biorefinery company, and is also a member of the Advisory Board of Applied Bioplastics, a supplier of plant-based plastic alternatives. Jack is the author of *Lignin: Technology, Applications and Markets* published by RISI in 2017. He is also the author of *Nanocellulose: Technology, Applications and Markets* published by RISI in 2014; *Nanocellulose Producers, Products and Applications, A Guide for End Users*, published by TAPPI in 2017; *Nanocellulose Challenges and Opportunities: End User Perspectives*, published by TAPPI in 2018, and *Nanocellulose: Packaging Applications and Markets* published by RISI in 2019. He has also presented on cellulose nanomaterials and lignin at webinars and conferences in the United States, Canada, Europe, South America, and Asia, as well as at conferences on packaging, composites, nonwovens, adhesives, textiles, and other nanomaterial applications.

This study is the product of extensive primary and secondary research.

Primary research includes direct input from more than 40 mills, biorefineries, research centers and technology providers. This includes interviews conducted by Biobased Markets, by telephone and email. In addition, draft profiles were sent to more than 50 key players for review and validation, and close to 50% have responded and provided input. Primary research included direct input from the following:

- Andritz AG
- Avantium N.V.
- BioProducts Institute
- Blue BioFuels, Inc.
- CellMark AB
- CH-Bioforce
- Chemtex Global Corporation
- Clariant AG
- CMPC
- FPIInnovations
- Futurity Bio-Ventures Ltd.
- G+E GETEC Holding GmbH
- Graanul Biotech
- GranBio Technologies
- Klabin S.A.
- LignoPure
- Liquid Lignin Company
- MetGen Oy
- North Carolina State University
- Ørsted A/S
- Praj Industries Ltd.
- Pure Lignin Environmental Technology, Ltd.

- Ren Com AB
- RenFuel AB
- Sainc Energy
- Sappi Limited
- Svensk Etanol Kemi AB (Sekab)
- Södra
- Stora Enso
- Suzano S.A.
- Sweetwater Energy
- Techlake
- University of British Columbia
- University of Maine
- University of North Carolina
- UPM Biochemicals
- US Forest Service
- Valmet Oyj
- Versalis S.p.A.
- Wageningen University

Secondary research includes an extensive review of patents, technical journals, conference presentations, magazine articles, and websites. Sources are referenced in the footnotes, as well as in Tables and Figures, many with live hyperlinks to the source material.

This study also builds on research conducted by Jack Miller in conjunction with the 2017 study *Lignin: Technology, Applications and Markets*.

This is a market study, not a technical journal, but it necessarily includes some technical discussion. Some may find it too technical while others may find it not technical enough. I have tried to strike a balance.

I thank technical advisors, Michael Paleologou of FPIInnovations, Orlando Rojas of the University of British Columbia, Hasan Jameel of North Carolina State University, and Michael Lake of Techlake and Liquid Lignin for their support with technical details. These advisors not only answered questions and provided input, but also reviewed sections of the report and suggested valuable edits. For those who want further technical research, a Bibliography is provided in Chapter 14.

Scope

The scope of this study is global. It covers kraft lignin, lignosulfonates, and biorefinery lignins. It includes discussion of biorefineries that have a reasonable likelihood of producing and recovering lignin and lignin-based chemicals. Lignocellulosic biorefineries that are primarily designed for biofuels, bio-diesel, etc. are generally not within the scope of this report.

Notes

More than 200 discrete sources are referenced, with active hyperlinks provided where possible, and underlined in [blue type](#).

This report uses both terms: “ton” and “tonne.” A ton, sometimes called short ton, is 2,000 pounds. A tonne, or metric tonne, is 1,000 kilograms, 2,204.6 pounds. We will generally use “tonne” except where the source uses the term “ton.”

The symbol “\$” is used to mean US dollars (USD or US\$) unless otherwise noted. The symbol € is used to mean euros. Other currencies except Canadian dollars (CAD) are converted to US\$. Currency symbols and abbreviations are defined in the Glossary.