RESEARCH BRIEF

Beyond Combustion: Unlocking the Value of Lignin 2026

Varsha Sethuraman
Senior Research Associate

LUX TAKE

Lux Take: Materials companies and other possible downstream end-users of lignin should explore applications where lignin can deliver a specific performance or cost advantage, then partner with lignin producers and processors to secure consistent grades for pilot validation. Pulp producers and biorefineries, by contrast, should avoid investing broadly in lignin upgrading until they have application-specific offtake partners that define the required purity, functionality, and price point.

There's a lot of underutilized opportunity in lignin. It's one of the most abundant biopolymers on Earth and is generated at industrial scale, with roughly 50 Mtonne/y of lignin are produced globally. But about 98% is incinerated for energy recovery, while the remaining 2% is being explored for conversion into higher-value products like aromatics, chemicals, and bioplastics. While lignin has heating value (though less than, say, propane), incinerating it is literally burning money: One study estimates that lignin converted into chemicals could be worth around USD 1/kg, versus roughly USD 0.2/kg when burned for energy.

Lignin's appeal as a feedstock comes from its high carbon content and phenolic and other reactive functional groups, which create opportunities for chemical modification and conversion into functional materials or chemicals. But the obstacle on its way to commercialization is its complex and variable structure. Lignin composition and performance vary depending on biomass source, growing conditions, and extraction method, making product consistency difficult to achieve. Most industrial lignin available today, including kraft and sulfite lignin, is also highly recalcitrant, dark in color, and often contains sulfur, which limits its suitability for many high-value applications. However, emerging lignin-processing technologies, along with advances in biomass pretreatment and fractionation, are beginning to address these limitations, resulting in lignin streams with improved quality and consistency and enabling access to higher-value applications for lignin and its derivatives.

To highlight the opportunities in lignin utilization beyond combustion and pinpoint the bottlenecks and caution signs, this analysis assesses:

1. Service providers characterizing lignin and connecting developers and markets.
2. Technology developers dedicated to transforming lignin, kraft or otherwise, into high-value products or developing novel pretreatment and fractionation technologies that yield high-quality lignin.
3. Key applications for lignin and its derivatives.

Lignin service providers

Lignin service providers have emerged over the past decade to help bridge the gap between lignin producers and potential end-users. Most offer characterization services that assess the properties of different lignin streams and help identify suitable applications. Some also advise lignin producers on downstream market opportunities or act as intermediaries between producers and companies seeking to incorporate lignin into product development. As one service provider told Lux, "Today, the connection between lignin producer and end-user is lacking, and therefore, there is limited feedback when it comes to product development."

Celignis (Ireland, founded 2013) is a specialized biomass analysis laboratory that focuses not just on lignin but also offers various services related to lignocellulose analysis. Its lignin characterization analysis packages include the separation of acid-insoluble and -soluble lignin to provide an understanding of lignin content as well as the syringyl-to-guaiacyl ratio, which helps evaluate lignin's reactivity, processing potential, and suitability for applications like biochemicals, resins, and biobased materials. Beyond lignin, Celignis assesses other key biomass components, including cellulose, hemicellulose, extractives, and ash. This holistic analysis aids in evaluating the suitability of biomass for various applications.

Lignopure (Germany, founded 2019) collaborates with industry partners and offers a range of services, including lignin characterization and benchmarking to compare customers' lignin with other lignins on the market, lignin tailoring and customized product development and prototyping, feasibility assessments to evaluate the commercial potential of lignin-based products, and support for value chain integration by exploring market fit.

Research Institutes of Sweden (RISE; Sweden, founded 1997) offers lignin characterization services, including assessments of lignin's chemical and molecular structures, purity, molecular weight, and thermal properties. RISE also owns and operates LignoCity, an open test and development facility located in Bäckhammar, Sweden, adjacent to the Nordic Paper pulp mill. The facility specializes in kraft lignin extraction and offers flexible production capabilities, allowing companies to produce tailor-made lignin grades in quantities sufficient for pilot testing. LignoCity provides an innovation hub where businesses can evaluate and validate new lignin valorization concepts for applications in biochemicals, biobased materials, fuels, and carbon products.

Key takeaways:

Clients exploring lignin valorization should engage characterization and application-development partners before committing to a target market, as lignin quality varies widely by feedstock, extraction process, and purification approach. Service providers like Celignis, Lignopure, and RISE can help translate lignin composition into application-relevant insights and identify which markets a specific lignin stream can realistically serve.

Emerging technology developers

Lignin processing

Process compatibility and product performance for lignin-derived products depend heavily on lignin type, purity, sulfur content, molecular weight distribution, and functional group profile. This has pushed the newest wave of lignin-processing developers away from broad claims about lignin as a drop-in renewable feedstock and toward narrower, application-specific strategies. Rather than trying to valorize lignin generically, startups founded over the past five years are building around defined combinations of feedstock, processing route, and end-market need — for example, kraft lignin for packaging coatings, sulfur-free lignin for cosmetics, colloidal lignin particles for coatings or adhesives, and depolymerized lignin for polyols or aromatic chemicals.

Earthodic (U.S., founded 2022) develops lignin-based barrier coatings for fiber-based packaging applications to replace polyethylene (PE) linings and wax coatings. The company uses dry kraft lignin, dissolved in an alkaline solution along with rheology modifiers and microfibrillated cellulose, to create a uniform, durable thin-film coating. The formulation can be integrated into existing coatings lines using roll-coating methods.

Level Nine (Germany, founded 2023) has developed nanozymes that can depolymerize lignin (either softwood or hardwood lignin) into monomers and oligomers. The company claims that the depolymerization process can occur under mild operating conditions because of the composition of the nanozymes. Level Nine's initial product focus is polyol production.

Lignoflow Technologies (Sweden, founded 2022) has developed a technology to create colloidal lignin nanoparticle dispersions by mixing different types of lignin in water. The resulting gel-like colloidal lignin offers performance benefits, including shear-thinning behavior, dust-free processing, and efficient mass transfer. The company's initial product focus is foam and is part of the TreeForm project to produce foams containing 50% lignin by weight and more than 90% biobased content.

Lignovations (Austria, founded 2021) produces colloidal lignin particles by precipitating lignin with an organic solvent. The process can adjust the particle size, yielding either nano- or non-nanoparticles. The company uses sulfur-free lignin and positions its first product, LignoGuard, for cosmetic applications, specifically sunscreen, blemish balm/color correction cream, face masks, makeup, or antiaging formulations. Lignovations is also working on other applications, including packaging, coatings, agrochemicals, and polymers.

LigniLabs (Germany, founded 2022) has developed a process to encapsulate substances into lignin nano- and microparticles. The company modifies kraft lignin with methacrylic anhydride to produce methacrylated kraft lignin, dissolves it in chloroform with the active substance, and uses ultrasonication to create a stable miniemulsion with an aqueous surfactant phase. This process yields lignin nanocarriers 200–300 nm in diameter with encapsulation efficiencies of 70%–99%, depending on the encapsulated substance.

Lignosphere (Finland, founded 2022) has developed a process to produce colloidal lignin particles by dissolving lignin in an organic solvent, aldehyde-functionalizing it in solution, and forming a colloidal dispersion by adding water as a nonsolvent. The company partially removes the organic solvent, heat-cures the dispersion, and spray-dries it to obtain dry, redispersible lignin particles with diameters of 320–395 nm. The process is compatible with technical lignins, including kraft lignin. LignoSphere is targeting coatings and adhesives.

Linium Biochemicals (France, founded 2023) uses a photochemical process to depolymerize lignin into monomers and oligomers. The company is testing feedstocks like cacao shells, almond shells, nutshells, tree leaves, and agricultural residues, but the feedstocks must have a minimum lignin content of 20%. The company offers two families of products: 1) aromatic monomers for food and fragrance applications, pharmaceuticals and cosmetics, dyes, and more, and 2) aromatic polymers for polyurethanes (PUs), epoxy resins, adhesives, and more.

Nova Biochem (U.K., founded 2023) has developed a continuous, catalyst-free hydrothermal depolymerization process to convert kraft black liquor of the pulp and paper industry into biobased aromatic monomers and oligomers. The process is designed to operate within the constraints of the pulp mill's recovery cycle, allowing return of inorganics while extracting value from a historically underutilized stream. Novabiochem's current product focus is guaiacol and vanillin, for the flavor and fragrance industry, and future focus incudes cresols and benzene-toluene-xylene molecules.

Key takeaways:

Clients looking for lignin valorization partners should prioritize developers that are moving beyond generic "lignin upgrading" claims and targeting specific applications with defined customer requirements. Favor startups that can show formulation data, compatibility with existing manufacturing equipment, customer validation, and a credible path from pilot-scale production to commercial supply.

Pretreatment and fractionation technologies

Companies developing novel pretreatment and fractionation technologies have gained traction as interest grows in fuller utilization of lignocellulosic biomass. Unlike conventional pulping processes, which often produce lignin streams that are highly condensed, contain sulfur, or difficult to valorize, these approaches aim to separate biomass into cleaner cellulose, hemicellulose, and lignin fractions. By preserving lignin structure, improving purity, or reducing degradation during separation, these processes can create lignin streams better suited for downstream use in chemicals, polymers, resins, coatings, fuels, and functional materials.

Bloom Biorenewables (Switzerland, founded 2019) has developed an aldehyde-assisted fractionation process that stabilizes the lignin and hemicellulose fractions of lignocellulosic biomass while separating the cellulose fraction. Its organosolv process uses dioxane as a biomass treatment, chloric acid as a catalyst, and formaldehyde as a stabilizer. Unlike most organosolv processes, which degrade the lignin fraction, Bloom's process leaves it intact. This is important because degradation impacts lignin's ability to be further depolymerized.

Boreal Bioproducts (Finland, founded 2018) uses spruce sawdust as feedstock to produce sulfur-free lignin and other bioproduct streams. Its product portfolio includes SpruceLigno, a native, low-molecular-weight lignin positioned for applications that benefit from UV absorption, antioxidant activity, and sulfur-free composition. Boreal has also moved beyond lignin supply into application development: it introduced SpruceLigno Soft, a lighter-colored and more water-dispersible lignin grade, and launched LigNoFog, a lignin-based anti-fog product for swim goggles and diving masks.

CH-Bioforce (Finland, founded 2016) has developed BIOFORSENSE, a pressurized hot-water-based biomass fractionation process that separates cellulose, hemicellulose, and sulfur-free lignin in a single process. CH-Bioforce claims that its lignin can be used in cosmetics, adhesives, bioplastics, and carbon fibers, and recent public materials suggest cosmetics and personal care are becoming a more concrete near-term focus. Its lignin-derived ingredient LIGNENSE is positioned for antioxidant and UV-absorbing functionality in cosmetics.

Chempolis (Finland, founded 1995) uses an organosolv process based on formic acid, acetic acid, and water to separate lignocellulosic biomass into cellulose, hemicellulose, and lignin streams. Chempolis can further recover and modify lignin through controlled precipitation, solvent extraction, and functionalization to tailor molecular weight, reactivity, and solubility. In 2024, Chempolis announced that AM Green would acquire a majority stake in the company and that Fortum’s Bio2X business would be transferred to Chempolis, positioning it as part of a larger industrial biorefinery platform rather than a stand-alone startup-like developer.

Fibenol (Estonia, founded 2018) uses a mechanical and chemical pretreatment process to fractionate woody biomass. The output contains a liquid fraction rich in monosaccharides and a solid fraction containing cellulose and lignin particles, which Fibenol further separates and processes. The company is positioning its lignin for applications such as bitumen replacement or modification in asphalt, bioplastics, and battery materials. In October 2025, Fibenol partnered with Tanovis to accelerate commercial lignin applications, beginning with animal feed through Tanovis subsidiary Phytaxis and expanding into biobased materials and chemicals.

Lixea (Sweden, founded 2017) uses ionic liquids (IL) to break down woody biomass into cellulose fibers, purified lignin, and hemicellulose-derived chemicals. The company introduced a range of lignin grades that can be fractionated into higher- or lower-molecular-weight fractions, with improved or reduced hydrophobicity, and used in applications such as epoxy resins and bitumen.

Key takeaways:

Cleaner lignin streams from pretreatment and fractionation developers like Fibenol and Chempolis could expand higher-value lignin applications over the next five years. Clients should engage early to test whether improved purity, sulfur-free composition, or preserved functionality creates a viable fit for target products — and to avoid building around lower-quality technical lignin that may limit performance.

Key applications for lignin and its derivatives

Key applications for lignin and its derivatives are diverse, reflecting growing interest in replacing fossil-based materials with renewable, lower-carbon alternatives. These substitutions are most attractive where lignin can maintain or improve performance while also offering cost, regulatory, or sustainability advantages. However, lignin quality, consistency, purity, reactivity, color, odor, and compatibility with incumbent formulations all influence whether it can move beyond niche use.

Lignin-based phenolic resins are one of the most established opportunities for lignin valorization. Lignin's aromatic structure and phenolic hydroxyl groups make it a potential partial substitute for petroleum-derived phenol in phenol-formaldehyde resin formulations. These resins are relevant for wood adhesives, construction materials, insulation foams, and related applications where thermal stability, mechanical strength, and adhesive performance are critical. Market interest is supported by pressure to reduce reliance on fossil-derived phenol and address formaldehyde emissions from resin-containing products. The Viobond project, for example, plans to begin operations at a 45,000-tonne/y facility in Latvia in Q3 2026, with collaborators including Saint-Gobain and Latvijas Finieris. However, lignin substitution rates in phenolic resins are often limited by lignin's lower reactivity, steric hindrance, and structural heterogeneity; many formulations still rely on partial replacement (typically 5% to 10%) rather than full substitution.

Lignin-derived polyols are positioned as alternatives to petroleum-based polyols for use in PU foams, coatings, adhesives, and elastomers. Lignin's hydroxyl groups and rigid aromatic structure can improve thermal stability, flame resistance, and mechanical strength when incorporated into PU formulations. Market interest is growing as polyurethane manufacturers look for lower-carbon feedstocks and higher biobased content. Startups like Level Nine are targeting lignin-derived polyols, while broader research activity continues around lignin-modification routes. Commercial adoption remains limited by lignin's heterogeneity, poor solubility, and lower reactivity compared with conventional polyether or polyester polyols, often requiring chemical modification such as oxypropylation, liquefaction, or other functionalization steps to improve compatibility and processing.

Lignin-based barrier coatings and films for packaging are gaining interest as brands, converters, and regulators seek alternatives to fossil-based coatings like PE linings and waxes. Lignin can be used in stand-alone coating systems or blended with conventional polymers and bioplastics, including PE, PP, polylactic acid, polyhydroxyalkanoates, and polybutylene adipate terepthalate. Its hydrophobicity, aromatic structure, UV absorption, and antimicrobial properties can support improved water resistance, oxygen barrier performance, light protection, and packaging durability. However, food-contact applications face higher hurdles around migration, odor, color, long-term stability, and regulatory approval. Nonfood packaging applications, such as agricultural mulch films, protective shipping materials, and industrial packaging wraps, may face lower qualification barriers, but cost and processability remain critical. Activity is increasing: Earthodic is developing lignin-based barrier coatings for fiber packaging, while Lignin Industries is scaling lignin-based pellets for use in plastics and elastomers.

Cosmetics and personal care represent a higher-value but more demanding opportunity for lignin. Lignin's phenolic groups can provide antioxidant, antibacterial, and UV-absorbing properties, making lignin relevant for skin care, sun care, color cosmetics, and formulation stabilization. Interest is supported by demand for biobased ingredients and regulatory pressure on microplastics and certain synthetic chemicals. But cosmetics applications require high-purity lignin, consistent color and odor, toxicology data, regulatory approvals, and reliable performance in complex formulations. Lignopure and Lignovations are among the most visible developers in this area: Lignopure has obtained an International Nomenclature Cosmetic Ingredient name registration for LignoBase, while both companies have partnered with distributors to support commercialization.

Lignin-based fillers offer a sustainable alternative to carbon black and mineral fillers like talc and calcium carbonate. In rubber and polymer composites, lignin can improve mechanical properties such as tensile strength and modulus, while also contributing to thermal stability and lower fossil-carbon content. These attributes are relevant for automotive components, tires, and durable goods. However, achieving optimal performance often requires compatibilizers or chemical modifications to enhance compatibility with polymer matrices. These additional processing steps add complexity and costs, which may limit widespread adoption.

Lignin-based materials for infrastructure applications like asphalt additives, concrete plasticizers, and construction materials are attractive because they can absorb large lignin volumes even at relatively low substitution rates. In asphalt, lignin can partially replace or modify fossil-derived bitumen, potentially improving stiffness and reducing life cycle carbon intensity. In concrete, gypsum, and cementitious systems, lignin-based dispersants and plasticizers can lower water-to-cement ratios and improve workability or compressive strength. These markets offer scale, but they also require extensive validation because infrastructure materials must meet long service-life, durability, aging, cracking-resistance, and regulatory requirements. Fibenol's partnership with Taisei Rotec to qualify lignin-based asphalt under Japanese road specifications and work by Metsä Group, VTT, and Andritz on lignin-based plasticizers in Finland suggest growing industrial interest.

Lignin-derived carbon materials offer a route to hard-carbon anodes for sodium-ion batteries and activated carbon for supercapacitors. Lignin's high carbon content makes it a suitable precursor for hard carbon production, while its availability from pulp and biorefinery side streams supports regional battery material supply chains. Market interest is increasing as sodium-ion batteries gain traction for stationary storage and low-cost mobility applications, particularly in Europe. For example, Fibenol and UP Catalyst are developing lignin-derived hard carbon and activated carbon materials for sodium-ion batteries and supercapacitors, while Stora Enso supplied lignin-based hard carbon for to Altris for sodium-ion battery cells. However, commercial adoption remains limited by lignin's structural variability, impurities, low carbon yields, and energy-intensive processing requirements, which can affect electrochemical performance, reproducibility, and cost-competitiveness compared with incumbent carbon materials.

Key takeaways:

Clients looking to develop lignin-based products should prioritize applications where lignin's inherent properties — aromaticity, carbon content, UV absorption, antioxidant activity, hydrophobicity, or filler functionality — create a clear performance advantage or addresses a sustainability pain point for an existing product. Near-term opportunities are likely strongest in adhesives and resins, fillers, infrastructure materials, packaging coatings, and selected polymer blends, while higher-value markets like cosmetics, specialty coatings, and battery carbon materials require tighter control over purity, color, odor, regulatory performance, and long-term consistency.

Outlook

The lignin industry is entering a transition phase in which commercialization will depend less on treating lignin as a single interchangeable feedstock and more on matching specific lignin streams, processing routes, and end-market requirements. Over the next decade, adoption will likely concentrate first in applications that can tolerate technical lignin variability or absorb large volumes at relatively low substitution rates, such as infrastructure materials, fillers, adhesives, and selected polymer blends, while higher-value specialty applications like cosmetics, advanced coatings, and battery materials will require tighter control over purity, consistency, color, odor, molecular structure, and regulatory performance. Biorefineries and pulp producers will continue exploring lignin valorization to improve plant economics and reduce reliance on low-value combustion, but structural barriers remain, including fragmented supply chains, inconsistent lignin quality, limited downstream processing infrastructure, and insufficient long-term validation against incumbent materials.

The best-positioned developers will be those that integrate lignin characterization, modification, formulation, and application development into a coordinated commercialization strategy. In practice, success will depend on turning variable sidestreams into reliable, application-ready products — not simply proving that lignin can replace fossil-based inputs in principle.

About Lux

Lux Research helps organizations make more confident decisions about the opportunities that matter next.

The world's leading companies rely on Lux to navigate uncertainty, identify emerging opportunities, and make smarter decisions about innovation and growth.

For innovation leaders, that means identifying future growth opportunities, determining which technologies deserve investment, and selecting the right innovation partners.

For insights leaders, it's identifying consumer opportunities, determining which cultural trends deserve action, and building products and brands that win.

Our multidisciplinary team of scientists, engineers, anthropologists, and industry experts combines original primary research, proprietary methodologies, and AI-enabled tools to connect customer needs, technology innovation, and market reality.

The result is better decisions that help organizations:

- Prioritize investments by focusing resources on the opportunities with the greatest potential.
- Reduce risk through independent expert judgment, primary research, and defensible decision frameworks.
- Accelerate business impact by helping teams move from insight to action faster.

Whether through ongoing research subscriptions with unlimited analyst access and Lux AI, or project-based advisory engagements, we help organizations separate signal from noise and focus on what matters next.

For More Information

VISIT
www.luxresearchinc.com

READ
www.luxresearchinc.com/blog/

CONNECT
www.linkedin.com/company/lux-research

FOLLOW
@LuxResearch

CONTACT
questions@luxresearchinc.com

Lux
Research