2012 Presidential Green Chemistry Challenge Awards Nomination
Zero Formaldehyde, High Strength Biocomposites
From Sustainable Resources
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Project Title: Zero Formaldehyde, High Strength Biocomposites from Sustainable Resources

Most recent milestone: e2e recently announced a 100,000 sf manufacturing expansion on the heels of successful pilot production in 2011 responding to strong demand for its commercial office furniture products.

The nominated technology is eligible for the small business award because e2e Materials has annual sales of less than $40 million.

The EPA award focus area that fits the technology is the design of greener chemicals.

The research and development of the technology occurred within the U.S. in Ithaca, NY. Manufacturing of the product was also done in New York state.

Abstract:
e2e Materials commercializes the next generation of products traditionally made from wood composites using a material technology that is stronger and lighter than wood composites and contains no formaldehyde. Refining technology developed by e2e co-founder Professor Anil Netravali at Cornell University, and licensed exclusively by e2e, the company stands to redefine the wood products industry with higher performing, safer, more efficient, cost effective cutting edge bio-composite-based products. For the office environment, e2e's technology enables products that achieve the highest sustainability and safety ratings in the Pharos Project and Living Building Challenge frameworks.. Today's furniture significantly contributes to Sick Building Syndrome due to the use of formaldehyde and VOCs (Volatile Organic Compounds) in conventional coatings, binders and laminates. e2e's inherent cost effectiveness enables a fully cost competitive product solution complimenting its proprietary biocomposite core with the greenest, cost effective coating technologies resulting in products with no VOCs that exceed today's performance standards.

e2e's proprietary chemistry enables a natural resin system when combined with bast fibers creates a material that is 3 to 4 times stronger than today's wood composites (Particleboard and Medium Density Fiberboard) and multiples stronger than most plastic. The unique ability to three-dimensionally form or net-shape the material creates whole, structural components replacing 4x8 sheets and subsequent process

steps and transportation costs. In addition to creating stronger components by formed rather than assembled joints, the material has superior screw retention compared to wood composites and is inherently fire-retardant. These combine to create furniture that is stronger and better performing while reducing the total amount of material and weight.

In addition to the hydrocarbon-free, safe furniture solution the company's technology enables a unique sustainable and cost-competitive solution. Localizing agricultural co-product feedstocks, combined with processes that use dramatically less energy comparably results in 19% of the embodied energy of wood composites. Replacing a supply chain that includes resin suppliers, wood composite manufacturers, and distribution of 4x8 sheets that then are cut, sanded, routed, drilled and assembled into furniture components allows the company to create globally competitive American manufacturing jobs. Products made from today's wood composites represent a $100 billion market opportunity.

The chemistry of e2e's biocomposite technology:
e2e is the exclusive licensee of technology developed at Cornell University by e2e co-founder Professor Anil Netravali. Over 4 years e2e has refined this technology and perfected it for the commercial market through performance enhancements, cost reductions, and process improvements.

Much great synthetic chemistry has been developed to produce the high strength resins and fibers used in modern composite materials. Unfortunately, these materials are based on the ever-dwindling supplies of hydrocarbon feedstocks. As the world's population continues to grow and fossil carbon resources continue to decrease in availability and increase in price, these fossil based chemical and energy streams will become ever less sustainable and cost effective. Additionally, at the end of their useful life products manufactured with some of these composites are difficult to recycle or degrade and are thus destined to reside in landfills for hundreds, if not thousands, of years

e2e has innovated a new approach reinventing today's wood products leveraging annually renewable, solar energy based polymers developed by mother nature over millions of years of experimentation. e2e's biocomposite material is made from lignocellulosic fibers, soy protein and plant polysaccharides with strength characteristics several times higher than those of conventional building materials such as particleboard and medium density fiberboard. Nature's primary reinforcing fiber, cellulose, is the most abundant polymer on earth and has specific strength characteristics that can exceed those of E-glass, used in fiberglass. These natural reinforcement fibers also have the advantage of lower density, which is particularly

important for lighter weight applications in the transportation industry. Additionally, natural fibers are less expensive than the synthetic alternatives. When harvested from rapidly growing species such as kenaf, jute, hemp and flax, lignocellulosic fibers are 100% annually renewable and can be grown on marginal lands. The growth of this fiber crop can sequester atmospheric carbon dioxide at a rate of at least 7.5 tons per acre per season. These long bast fibers from sources including kenaf, jute, flax and hemp contribute to higher strengths ways that cannot be accomplished with the short wood fibers used in particleboard and MDF.

In the e2e composite system, the long bast fibers are bound together with a resin composed of soy protein and polysaccharides. Soy protein contains a number of amino acids that have reactive polar side chains, such as carboxyls, amines and hydroxyls (see Figure 1 below). Once processed, protein itself can form crosslinks through the –SH groups present in the amino acid cysteine as well as through the dehydroalanine (DHA) residues formed from alanine by the loss of the α-hydrogen and one of the hydrogens on the methyl group side chain, forming an α,β-unsaturated amino acid. DHA is capable of reacting with lysine and cysteine by forming lysinoalanine and lanthionine crosslinks, respectively. Asparagines and lysine can also react together to form amide type linkages. All these reactions can occur at higher temperatures and under pressure that is employed during curing of the protein. These polar groups also interact with the hydroxyl groups of cellulose (see Figure 2 below) and the carbohydrate portion of the soy can interact with the protein component by the Maillard reaction. During the final curing and shaping step, pH, temperature and pressure are carefully controlled to yield a final net shaped product with the desired strength and density characteristics for each unique application. The final thermoset composite system takes advantage of the three natural polymer networks, protein, cellulose and polysaccharides to produce a composite of great strength and formability. e2e has commercialized products using this composite system without resorting to the addition of formaldehyde, isocyanates or other toxic additives.

At the end of their useful life, products built with this chemistry can be readily degraded by a great abundance of enzymes that exist in nature for this very purpose…. earth to earth. Several patent applications have been filed by e2e and published detailing e2e's technology and refinements.

- Cured Soy Protein with green strengthening additive and fabrication of such into green composite - US 11/407,329, Filed: Apr. 20, 2006
- Biodegradable plywood and method of manufacture US 12/058,739, Filed: Mar. 30, 2008
- High-strength, environmentally friendly corrugated board US12/809067, Filed: Dec. 17. 2008
- High-strength, environmentally friendly contoured articles US 61/014,209, Filed: Dec. 17, 2007
- Biodegradable resin composites - US 13/052,058, filed March 19, 2011

- Claims additional antimoisture and antimicrobial agents
- Dried biodegradable resins - US 13/086,533, filed April 14, 2011
  - Claims effective dry resin systems that greatly reduce energy consumption by eliminating the drying step
- Naturally-sourced building materials - US 13/086,527, filed April 14, 2011
  - Claims biocomposite building materials of varying densities

Figure 1

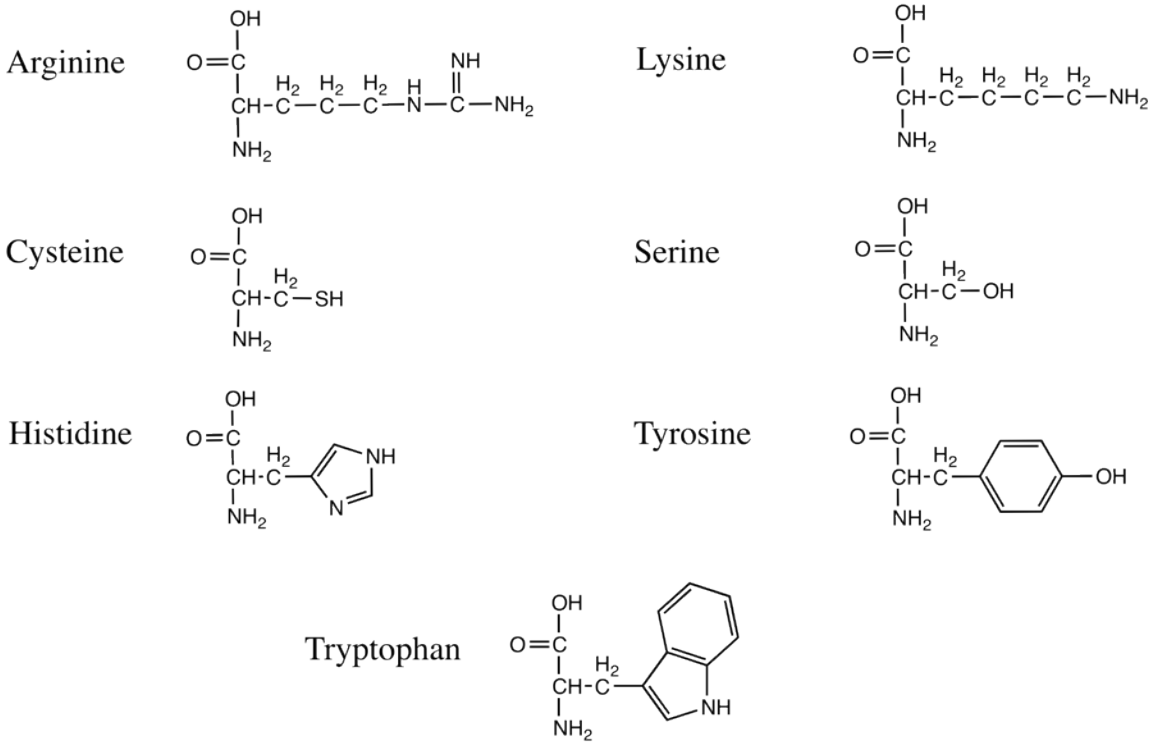
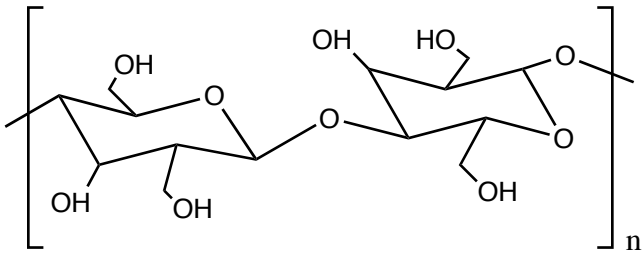


Figure 2



Cellulose

The problem that e2e's biocomposite material technology addresses:
e2e's biocomposite material technology addresses multiple problems on varying levels. There are not enough trees on the planet to satisfy the growing demand from China and India for building materials and furnishings for their homes, offices and schools as we do in the established Western economies there are not enough trees on the planet to satisfy that demand. With all of its key feedstocks coming from annually renewable agricultural sources – rather than 20+ years it takes to grow a tree- e2e represents the only sustainable solution capable of meeting this growing demand.

Using only 19% of the embodied energy of today's products and eliminating hydrocarbon feedstocks has the potential to cidramatically contribute to minimizing our dependence on petroleum. If e2e were to replace all products made from particleboard and MDF, it would have an environmental impact equal to 2.7 million Toyota hybrids.

e2e Embodied Energy Comparison			
	e2e Materials	**Particleboard**	**MDF**
Thickness:	**¼"**	**¾"**	**¾"**
Process:	*(expressed as lbs CO2 per 4'x8' sheet)*		
Fiber:	**12.36**	**71.50**	**34.34**
Resin:	**15.48**	**66.02**	**86.16**
Mfg:	**14.46**	**84.18**	**302.04**
Total:	**42.30**	**221.70**	**422.56**
e2e %		**19%**	**10%**
Industry Size (billions of lbs CO2)		**26.8**	**30.1**
Potential e2e Impact (billions of lbs CO2)		**22.9**	**27.8**

Today's office furniture significantly contributes to the problem of Sick Building Syndrom due to the use of formaldehyde and other VOCs (Volatile Organic Compounds) in today's materials, coatings, binders and laminates. Formally identified as a carcinogen in 2004 by the International Agency for Cancer Research, the elimination of formaldehyde has driven the need for change in the parochial wood products industry. In 2007, California (CARB) passed the Airborne Toxic Control Measure (ATCM) for composite wood phasing out formaldehyde offgassing (i.e. the release of chemical fumes used in constructing a product) starting in 2009 with the full limits taking effect July 1, 2012. In July 2010 national legislation was enacted, with the EPA adopting CARB rules nationally by January 1, 2013. In June 2011, the United States National Toxicology Program formally listed formaldehyde as a carcinogen and noted that it is found in worrisome quantities in plywood and particleboard. e2e's exclusive chemistries use no hydrocarbon or toxic feedstocks and its natural, annually renewable fibers contain no formaldehyde or VOCs. Zero.

How e2e's technology compares with other technologies that try to address the same problem:

Fundamentally we disruptively eliminate a number of steps today's supply chain which enables a number of competitive advantages:

Lowest Cost: Our proprietary, single-step three-dimensional forming (we call it net-shaping) replaces the production, distribution and transportation of 4x8 wood composite sheets and subsequent manufacturing processes that produce today's wood component assemblies while reducing costs and generating gross margins much higher than industry norms.

Highest Strength and Performance: Our proprietary biocomposite is 3 to 4 times stronger than wood composites and multiple times stronger than plastic creating product solutions that are stronger and better performing while reducing material and weight.

No Formaldehyde: In 2007, the California Air Resources Board (CARB) passed the Airborne Toxic Control Measure (ATCM) phasing out formaldehyde off-gassing for wood products full limits take effect 7/1/12. In July 2010 national legislation was passed, with the EPA adopting CARB rules nationally by January 1, 2013.

Lowest carbon footprint: Our product solutions contain only 19% of the embodied energy of those made from today's wood composites and use hydrocarbon-free feedstocks.

Healthiest products: Products made by e2e uniquely optimize indoor air quality, a primary component of green building standards. Recent studies[1] conclude that green office buildings improve worker productivity and reduce health related absenteeism. Willingness to pay more for such space has grown 13% since 2009.

e2e Materials Acoustic Panel

New Design Capability: Net-shaping provides product designers with new capabililties, inherent fire resistance provides the most cost-effective platform for integrating electronics and connectivity. Using natural pigments in our resin system offers frontiers in colors and finishes.

Highest Inherent Fire Resistance: Using a soy protein rather than petrochemical-based resin system offers inherent fire resistance, achieving the highest ratings compared to a variety of standards from target industries.

Reduced Transportation: 40% of the cost of today's building products is transportation. In addition to the impact of shipping lower weight products, our manufacturing model is most cost effective when we manufacture near our customers and source our agricultural supply chain regionally, eliminating lengthy transportation costs. We've coined the phrase "Regionally Integrated Manufacturing" to describe our simplified regional model that creates both significant shareholder value and economic impact.

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[1] *American Journal of Public Health* Study; Recent survey of real estate development firms by CoreNet Global and Jones Lang LaSalle;

The realized or potential benefits and drawbacks across all stages of the technology's lifecycle

Feedstocks:
e2e replaces carbon intensive products with annually renewable feedstocks. e2e's biocomposite is made of soy flour and bast fibers from plants such as kenaf, hemp, jute and flax. e2e can also utilize a number of crop residues and waste such as sugarcane bagasse, soybean stalks, and similar annual plant matter, as well as post-industrial and post-consumer recycled natural fibers. e2e's feedstocks sustainably address a growing, global population. The global demand for wood products today could be satisfied with less than 3% of the global soy flour production and fibers grown on land the size of New Hampshire.

Manufacturing:
In addition to it's competitiveness and energy efficiency, e2e's largest manufacturing benefit is economic. e2e's unique, efficient manufacturing process reduces process stepss and energy cost associated with today's 4x8 panels while offering a new design frontier through three-dimensional formability. The associated reduced cost enables an American manufacturing solution that is inherently competitive with imported products threatening today's manufacturing base. Regionalizing our fiber sources extends our sustainable economic impact into the regional agricultural base creating over 1,600 jobs per region. The company is piloting its regionalization model in upstate New York where it plans to source flax fiber regionally for it's new manufacturing facility in Geneva, New York.

Use of product:
e2e's office products set new standards in indoor air quality scoring this highest possible ranking in the Pharos Project and Living Building Challenge Frameworks. e2e's customers lead the open, safe office revolution and our products.


e2e Materials Mobile Whiteboard

Disposal of product:
e2e's biodegradable resin chemistries and natural fibers go through an enzymatic degradation. The same millions of years of experimentation that has resulted in the high strength natural polymers that form the e2e composite has also developed enzyme systems to completely break down this material and return it to the soil to be available for the next years' crop. The ultimate in sustainability.

e2e Materials in the Press:
Jetson Green: e2e Offers New Biocomposite Materials
e2e and CEO Whitehouse Profile
e2e ranks 37 in Top 300 Start-Ups for 2011
e2e expanding manufacturing operations