



Green+Clean

Renewable chemicals naturally designed and engineered to deliver the performance that adds value to everyday products.

What is Butanol (n-Butanol)?

Butanol is an alcohol that is produced through petrochemical processes, but can also be produced, like ethanol, through fermentation of sugars derived from corn and agricultural crops. Butanol is a four carbon alcohol; ethanol is a two carbon alcohol. Ethanol is primarily sold as a fuel blend stock for gasoline. N-butanol is sold primarily as a chemical. It's worth noting there are two types of butanol: normal butanol (or n-butanol) and isobutanol. While the two molecules possess similar characteristics, they have dramatically different uses. N-butanol is a superior global chemical with over 8 billion pounds of annual demand. Isobutanol is primarily marketed as a fuel blend stock similar to ethanol today and correspondingly has a much lower value as a fuel. As a chemical, Isobutanol has much more limited applications with around 800 million pounds of global demand.

Until the mid-1940's, n-butanol was produced predominantly through fermentation using a process called ABE with clostridia bacteria. The ABE process was developed in England in 1912 to produce acetone, which was used to manufacture armaments during World War One. In 1927, the ABE process shifted toward production of n-butanol to produce lacquers for the growing automotive industry. With the advent of cheap oil and the introduction of new petrochemical processes, the ABE process fell out of favor due to the more economical petrochemical route.

Modern biotechnology and advanced fermentation technology has changed all of that. With scientific advances in microbiology and synthetic biology and dramatic improvements in process technology, the ABE process is now economically equivalent to much larger petrochemical processes. Better yet, the advanced ABE process produces higher purity n-butanol with a carbon footprint that is over 45% better than petro-based butanol.



N-butanol is an intermediate used to produce high value resins and specialty solvents used in a wide variety of formulated products, from paints and coatings to cosmetics and fragrances, to adhesives and inks, and even food flavors and extracts. N-Butanol is used in plastics and polymers, brake fluids, lubricants, synthetic rubber, fire retardants, and many other applications. So while n-butanol is similar to ethanol, those two extra carbon molecules make a big difference. Butanol has great potential as a fuel, but its value as a chemical is more than 3 times the value of fuels.

As a chemical, n-butanol has an immediate market valued at over \$6 billion and downstream chemical intermediate markets valued at well over \$40 billion. These are high value products used to produce environmentally friendly, low-



VOC water-based paints, coatings, inks and adhesives. They are used as powerful but environmentally friendly solvents in cleaning products and waxes, as extractants in pharmaceuticals and artificial food ingredients, and as active ingredients in cosmetics. Butanol derivatives are used in shaving products and shampoos, as well as detergents and soaps. They're used to improve fragrances and perfumes, and to improve the taste of microwave popcorn. The following table breaks down where n-Butanol is used to produce its derivations through consumer products:

Derivative Product	Formulated Products	Consumer Products
Butyl acrylate	Water-based latex paints Pressure Sensitive Adhesives	Interior & exterior house paint Post-it® notes, labels, tape, Band-Aids®
Butyl acetate	Wood coatings Industrial/OEM coatings Automotive coatings Cosmetics Cleaning solvents	Furniture, cabinets, floors, marine Metal furniture, farm equipment, toys Auto OEM finishes, Auto repair Fingernail polish remover, personal care Household & industrial cleaners
Butyl glycol ethers	Water-based latex paints Cleaning solvents	Interior & exterior house paint Household & industrial cleaners
Butyl esters	Artificial flavors Plasticizers Cosmetic ingredients Lubricants	Food ingredients, artificial extracts Environmentally friendly plastics Various cosmetic & personal care products Aluminum cans, food manufacturing

With advanced process technology, existing ethanol plants can be repurposed to produce n-butanol and acetone at a scale and cost that allow cost competitive production and direct competition with the large, fully integrated petrochemical plants up and down the Houston ship channel. But it will be done in rural America, creating high value jobs in the clean renewable chemicals market.