Susterra® Propanediol Heat Transfer Fluids

Performance is in our nature.

March 11, 2016

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Who is DuPont Tate & Lyle?

DTL is a joint venture formed in 2004 between DuPont and Tate & Lyle to produce 1,3 propanediol (PDO) from corn starch, a sustainable & renewable resource

DuPont is a world leader in science and innovation across a range of disciplines, including agriculture and industrial biotechnology, chemistry, biology, materials science and manufacturing. CY2015 revenues were $35 billion.

Tate and Lyle is a global provider of renewable ingredients, solutions and services to the food, beverage and industrial customers. Revenues were $4.3 billion for Fiscal Year ending March 31, 2015.

DuPont Tate & Lyle BioProducts™

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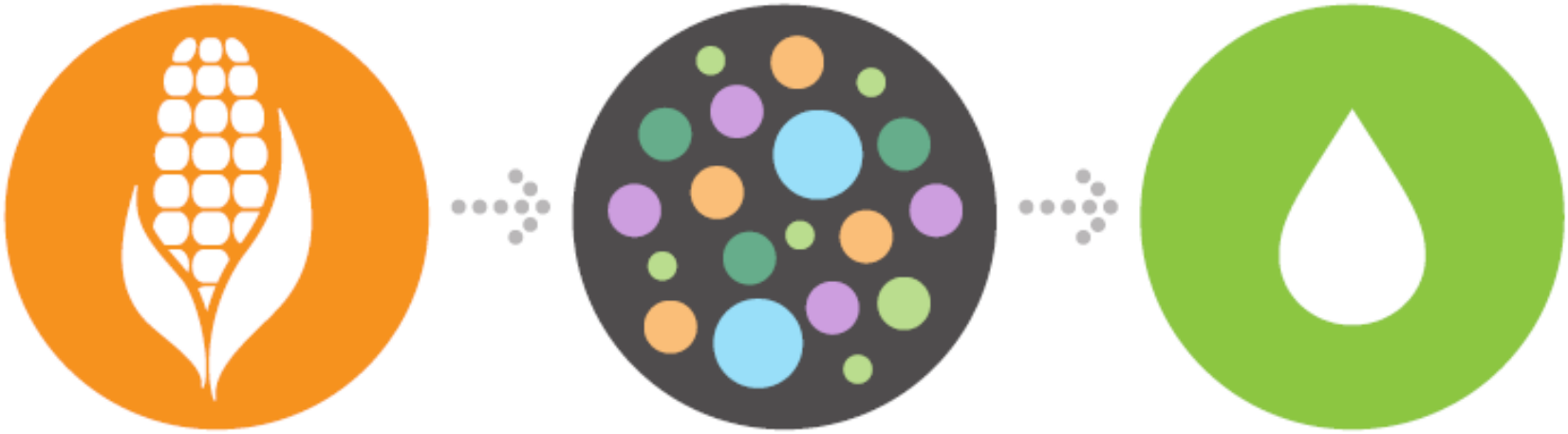
Process Technology

Renewably sourced feedstocks are harvested, fermented, and refined to manufacture Susterra® propanediol.



Harvest

Renewably sourced feedstocks are harvested, dried and then wet-milled to create a range of carbohydrate rich feedstocks such as glucose.

Fermentation

Glucose is converted into 1,3 propanediol using a patented microorganism under exact temperatures and conditions.

Refining

The 1,3 propanediol is refined to a final purity of 99.7% by deactivating and removing the microorganism, water, and other byproducts.

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Production

Biotechnology enables our global headquarters and production in Loudon, Tennessee to produce a stable supply of renewably sourced 1,3 propanediol

Awards

- 2003 EPA Presidential Green Chemistry Award
- 2007 ACS Heroes of Chemistry Award
- 2009 ACS-BIOT Industrial Biotechnology Award
- 2010 State of Tennessee Governor's Award for Trade Excellence

Production

- Started November 2006
- Capacity expanded 35% in 2010
- Current Capacity = 140 million lb.

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Susterra® Propanediol Process Flow

Fermentation

CO_2-enriched air

Dextrose
Air
Water
Biocatalyst
Nutrients

Separations

Product Storage Tanks

Water

Bioresiduals

Recycle

Trace Impurities

Not Meet Specification

QC

Meet Specification

Susterra® 1,3-Propanediol

Quality Checks
PDO Purity (GC)
Color (Hazen)
Water (Karl Fischer)
Appearance (Visual)

Re-use as fertilizer

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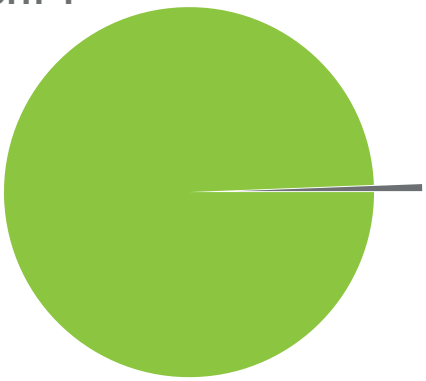
Field Corn vs. Sweet Corn

Susterra® propanediol is derived from U.S. Field Corn

Yellow Dent or "Field Corn":
90.6 MM planted acres
14.2 B bushels produced
Crop Value: $51.9 B



Sweet Corn:
0.555 MM planted acres
137 MM bushels produced
Crop Value: $1.02 B

Yellow Dent Facts:

- Grown on over 99% of U.S. corn field acres
- Produced for ethanol, livestock feed, cereals, and other manufactured goods
- Considered a grain
- Harvested when kernels are dry and mature

Sweet Corn Facts:

- Grown on less than 1% of U.S. corn field acres Consumed by humans
- Considered a vegetable
- Harvested when kernels are soft and immature

Source: Field corn statistics - U.S. Department of Agriculture, June 2015
Sweet corn statistics - U.S. Department of Agriculture, 2014

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Field Corn

Susterra® propanediol utilizes the starch in the field corn while the other components are harvested for different applications including animal feed for livestock.

Yellow Dent Corn Components:

- 62% Starch
- 19.2% Protein & Fiber
- 15% Moisture
- 3.8% Corn Oil

One bushel of wet-milled field corn

Produces

1.5 pounds of crude corn oil	13.5 pounds of gluten feed	2.6 pounds of gluten meal	31.5 pounds of starch
Used in consumer & industrial products	Used in animal feed	Used in animal feed	Used as the feedstock for Susterra® propanediol

Source: Tate & Lyle;
National Corn Growers Association

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Susterra® Propanediol

From the Field to Market Applications

DuPont Pioneer hybrids

DuPont enzymes

DuPont microorganism

Corn

Glucose

Bio-PDO™

DuPont™ Sorona®

Fiber

Carpet

Apparel

Auto

Personal Care

Zemea®

- Cosmetics and Personal Care
- Food and Flavors
- Laundry and Cleaning
- Pharmaceuticals

Industrial

Susterra®

- Heat Transfer Fluids
- Polyurethanes
- Unsaturated Polyester Resins
- Paints, Coatings, and Inks
- Deicing Fluids

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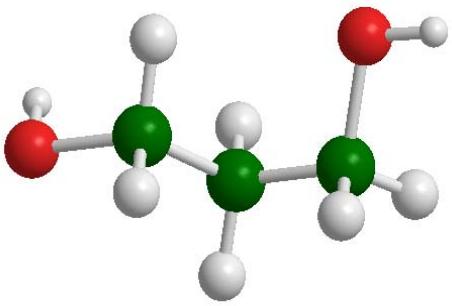
Susterra® Propanediol



What is it?

- A pure, petroleum-free derived glycol
- 100% sustainably and renewably sourced
- Used in a range of applications

USDA CERTIFIED BIOBASED PRODUCT
PRODUCT 100%

How is it made?

- Made by a fermentation process derived from glucose
- Made in the USA
- USDA 100% Certified Bio-Based Product
- GRAS, Halal, Kosher
- Ingredient for use in Heat Transfer Fluids with Incidental Food Contact (HTX-1)

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Susterra® Propanediol

Performance advantages in heat transfer fluids

- Improved viscosity at lower temperatures compared to PG
- Excellent freeze point depression for aqueous solution applications

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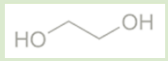
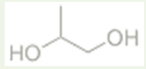
Susterra® Propanediol

Glycol comparison – chemical structure and property comparison

1,2- Propanediol (PG) and 1,3-Propanediol (PDO) have the same formula and molecular weight.

The difference between PG and PDO is the structure of the molecule. PDO is more linear giving it a higher BP and lower viscosity.

Common	Ingredient	CAS#	Formula	Structure	Mol. Wt.	BP, °C	MP, °C	Density
Ethylene Glycol	1,2-Ethanediol	107-21-1	C2H602		62.1	197.6	-12.7	1.116
Propylene Glycol	1,2-Propanediol	57-55-6	C3H802		76.1	187.3	-60	1.038
Propanediol	1,3-Propanediol	504-63-2	C3H802		76.1	214	-24	1.053

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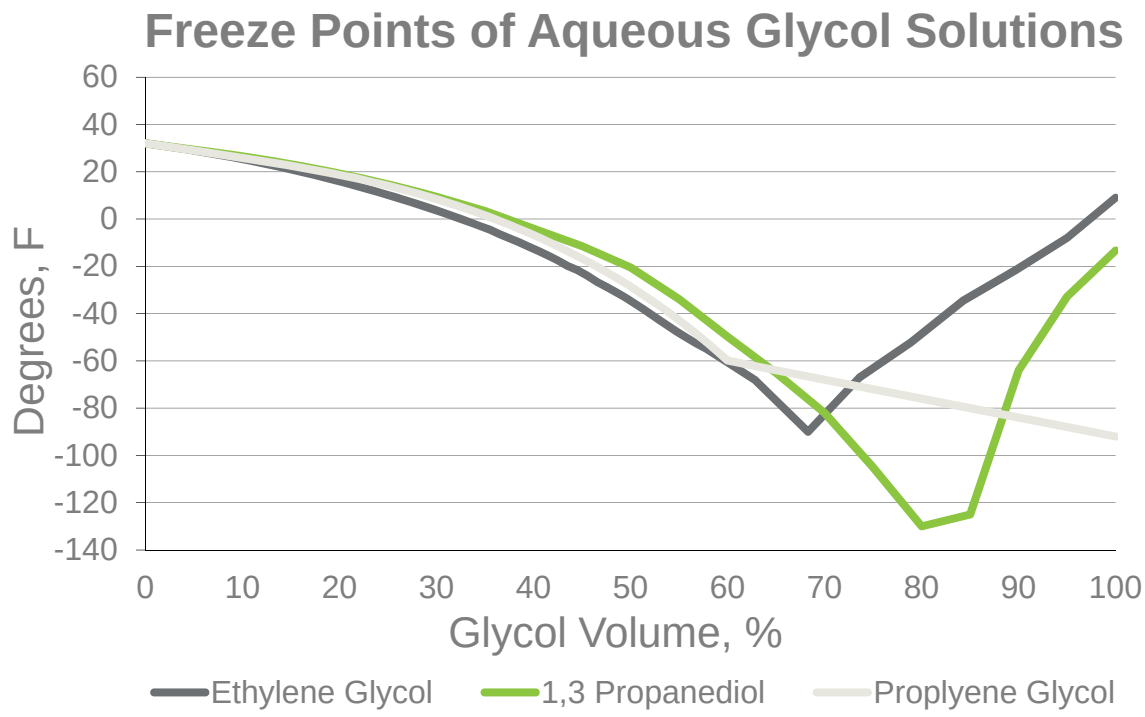
Susterra® Propanediol

Glycol comparison – property comparison

Susterra® propanediol exhibits lower freeze points at higher percentages of glycol.



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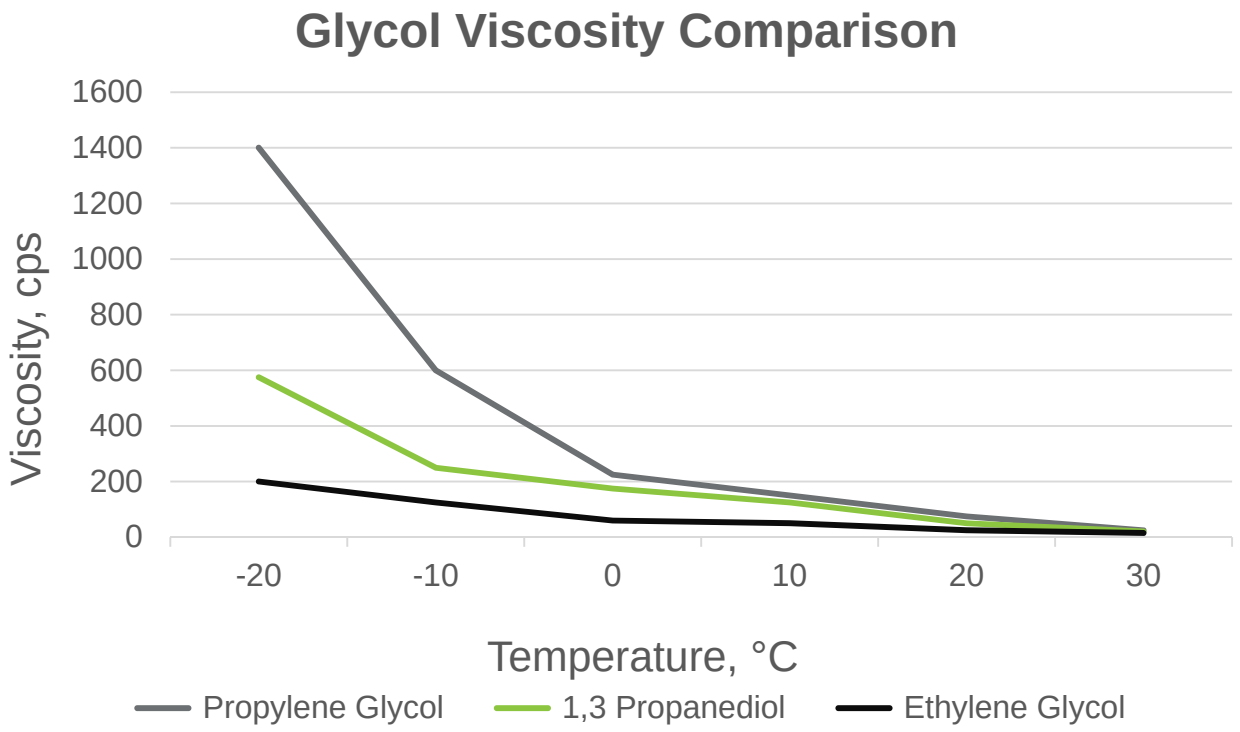
Glycol comparison – low temperature viscosity

Susterra® propanediol exhibits lower viscosity under low-temperature conditions



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Glycol comparison – pump power ratio

Objective: Determine the amount of energy needed to pump fluid 1 (propylene glycol) relative to fluid 2 (1,3-propanediol) in order to get the same heat transfer performance.

$$PPR_{12} = (\mu_1/\mu_2)^{1.95} (\rho_1/\rho_2)^{-0.05} (k_1/k_2)^{-2.3} (Cp_1/Cp_2)^{-1.05}$$

The pump power ratio compares the performance of different fluids.

PPR_{12} @ -10°C = 2.4

Properties at -10°C	40.5 wt % PG	40 wt% Propanediol
Absolute Viscosity (cP)	24.48	16.5
Density (0°C), g/ml	1.05	1.06
Specific Heat ($kJKg^{-1}K^{-1}$)	3.602	3.495
Thermal Conductivity ($Wm^{-1}K^{-1}$)	0.374	0.39
Kinematic Viscosity (cSt)[6]	23.3	15.5
Fp (°C)	-20	-20

The power required to pump a 40% PG fluid at -10°C is 2.4 times that of the pumping energy as a 40% Susterra® propanediol fluid.

Source: Sherwood, G. "Secondary Heat Transfer Systems and the Application of a New Hydrofluoroether"

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Susterra® Propanediol

Glycol comparison – pump power usage

Objective: Compare the pump power usage performance using two different heat transfer fluids for a food refrigeration system.

Operating temperature: 32 °F
Centrifugal Pump: 5 hp

Flow: 175 gpm
Head: 50 ft

Property	Propanediol, 30%	Propylene Glycol, 30%
Freezing point, °F (°C)	9.4°F (-12.6°C)	9.2°F (-13°C)
Density (0°C), kg/m3	1026	1030
Kinematic viscosity, centistokes	42	69
Power, (kW)	3.1	3.4
Power savings	8.9%	- n/a -

Using hydraulic institute standards to adjust for viscous liquids determines that pump power for Susterra® propanediol led to a 8.9% reduction in power usage.

Source: Hydraulic Institute Standards

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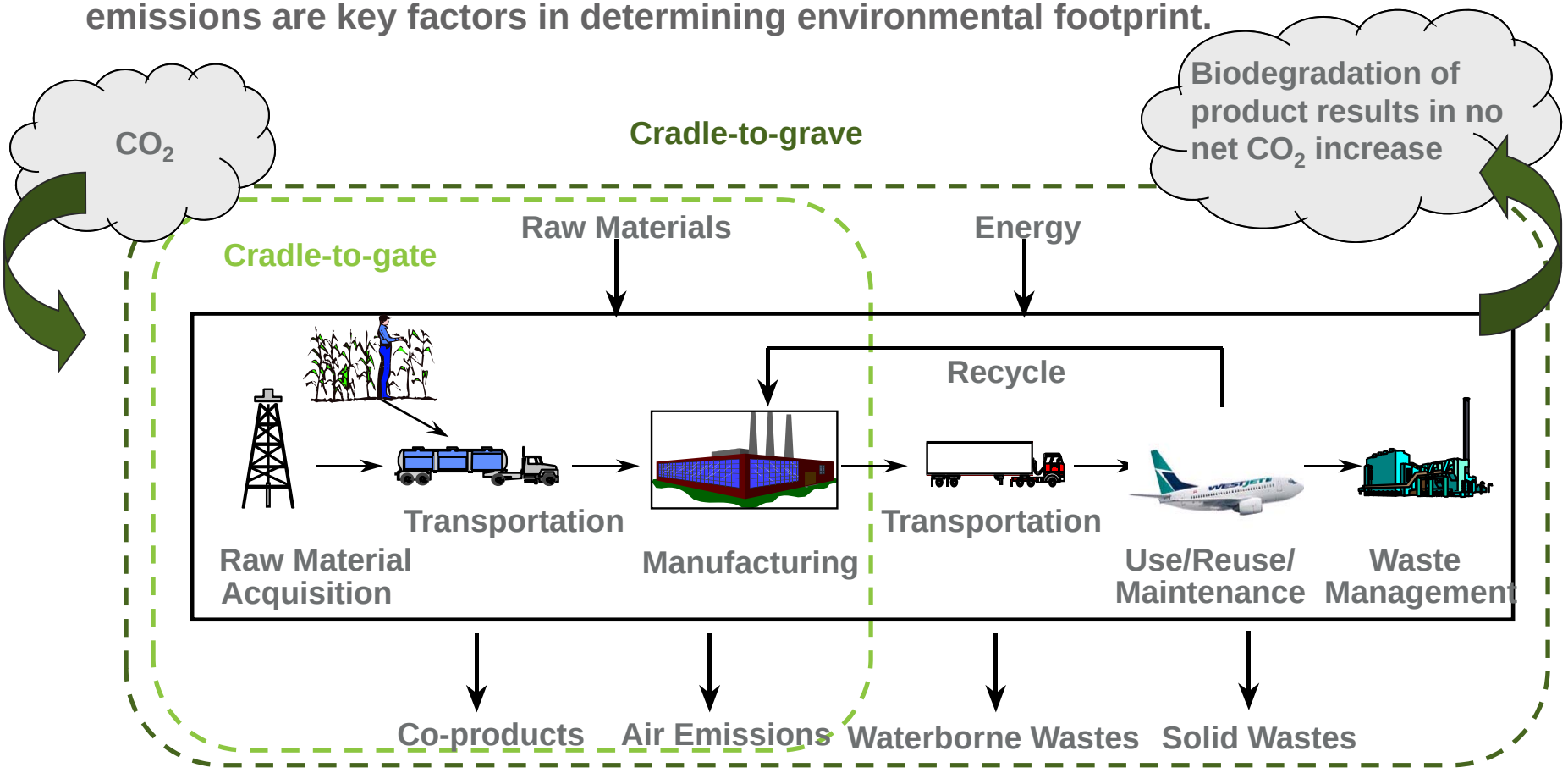
Life Cycle Analysis (LCA)

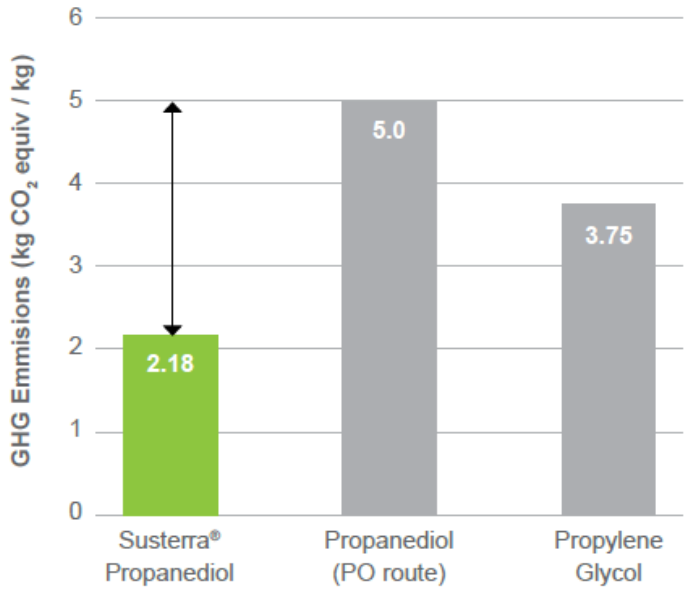
LCA is the only standardized method to evaluate the environmental footprint of a whole supply chain. Energy consumption and Green House Gas (CO_2) emissions are key factors in determining environmental footprint.



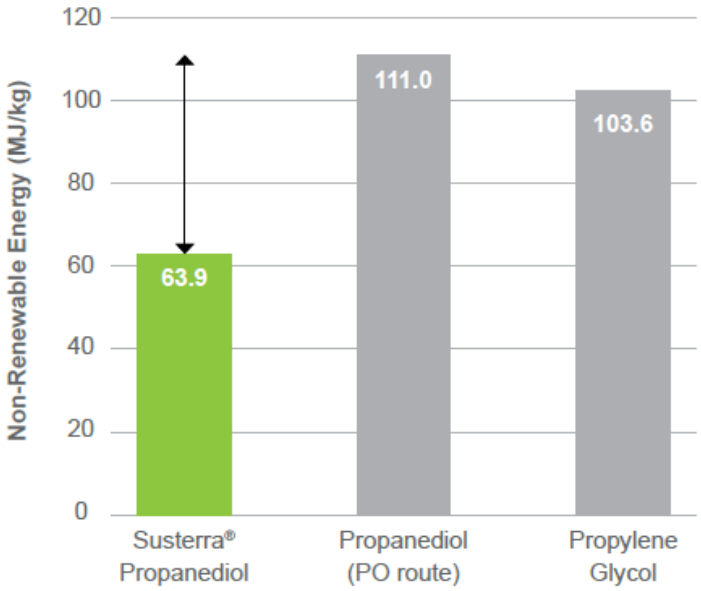
Life Cycle Analysis

Susterra® propanediol

From "cradle to gate" (extraction and production prior to delivery to the consumer), Susterra® propanediol produces 56% less greenhouse gas emissions and consumes 42% less nonrenewable energy than petroleum-based 1,3-propanediol. Compared with propylene glycol, Susterra® propanediol produces 42% less greenhouse gas emissions and uses 38% less nonrenewable energy from cradle to gate.



Greenhouse Gas Emissions
56% less than Propanediol
42% less than Propylene Glycol



Non-Renewable Energy Use
42% less than Propanediol
38% less than Propylene Glycol

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