

Bio-Based 1,3-Propanediol as Building Block in High-Performance Wood Coatings

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Wood Finishing: Raw Materials for the Formulation of Next-Generation Coatings and Vanishes

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TO BE COVERED

Introduction and Background

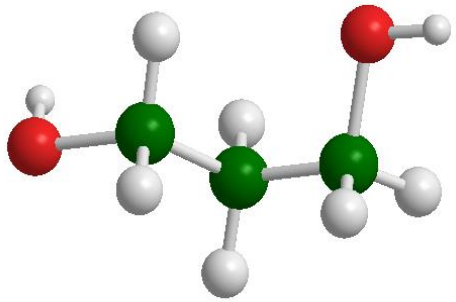
1,3-PDO a specialty building block monomer

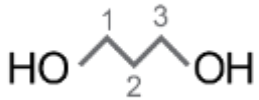
Functionalized 1,3-BioPDO into Reactive Diluent for UV wood coatings

Building block in alkyd synthesis to overcome viscosity issues.

Susterra® 1,3-Propanediol: What is it?

- A pure, petroleum-free derived glycol
- 100% sustainably and renewably sourced
- Susterra® propanediol is the building block that delivers high performance in a variety of applications, from polyurethanes and unsaturated polyester resins to heat-transfer fluids.



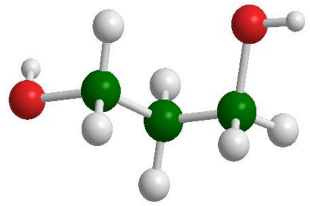


USDA CERTIFIED BIOBASED PRODUCT
PRODUCT 100%

GRAS, Halal and Kosher certified

Physical and Chemical Properties	Susterra® Propanediol
CAS Number	504-63-2
Molecular Formula	C3H8O2
Molecular Weight	76.1
Molecular Structure	HO-CH2-CH2-CH2-OH
Hydroxyl value	1475
Melting point, °C	-27.65
Boiling point, °C	214.22
Freezing point, °C	-24.0
Refractive Index, 20°C	1.436
Lower explosion limit, %vol	2.6
Vapor pressure @ 20 °C, hPa	0.0159
Vapor pressure @ 25 °C, hPa (mm Hg)	0.0267 (0.0200)
Vapor pressure @ 100 °C, hPa	8.77
Specific gravity @ 20 °C	1.053
Water solubility	infinity
Log Kow	-1.04
Auto-ignition temperature, °C	400
Viscosity, kinematic @ 20 °C / cSt	46
Viscosity, dynamic @ 20 °C / cP	49

1,3-Propanediol Susterra®



Perfect 3-carbon molecule for building block chemistry, as it is or further derivatized

- The only linear 3-carbon molecule. Non-toxic and highly sustainable.

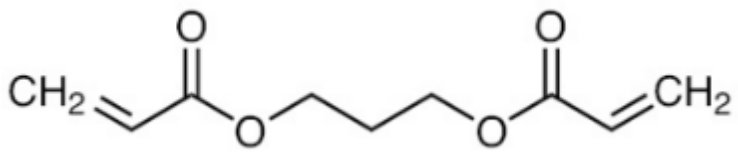
Due to the fermentation process our 1,3-PDO is extremely pure.

- Possesses no carbon-based residuals, generating a reliable synthesis.
- At least 99,7% purity.

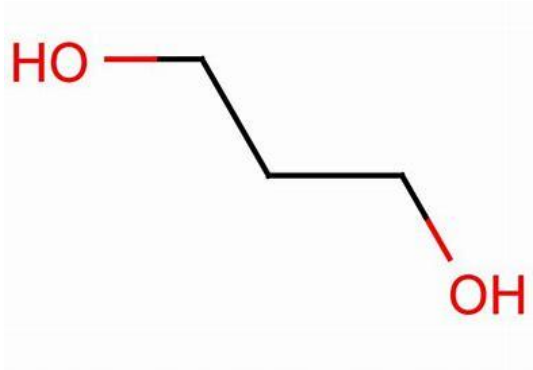
Replaces any diols and partly higher functional alcohol in polymeric resin systems.

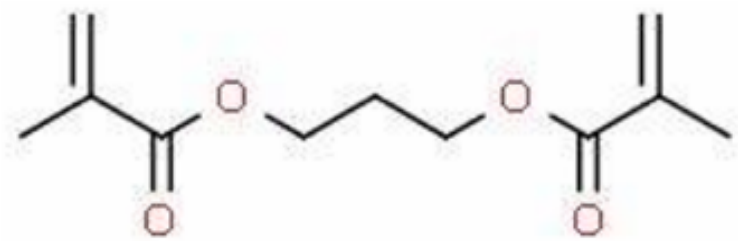
- Generating low viscosity and increased flexibility of the polymers
- Monomer building block for Alkyds and Polyesters

Susterra® 1,3-Propanediol derivatized into reactive diluent



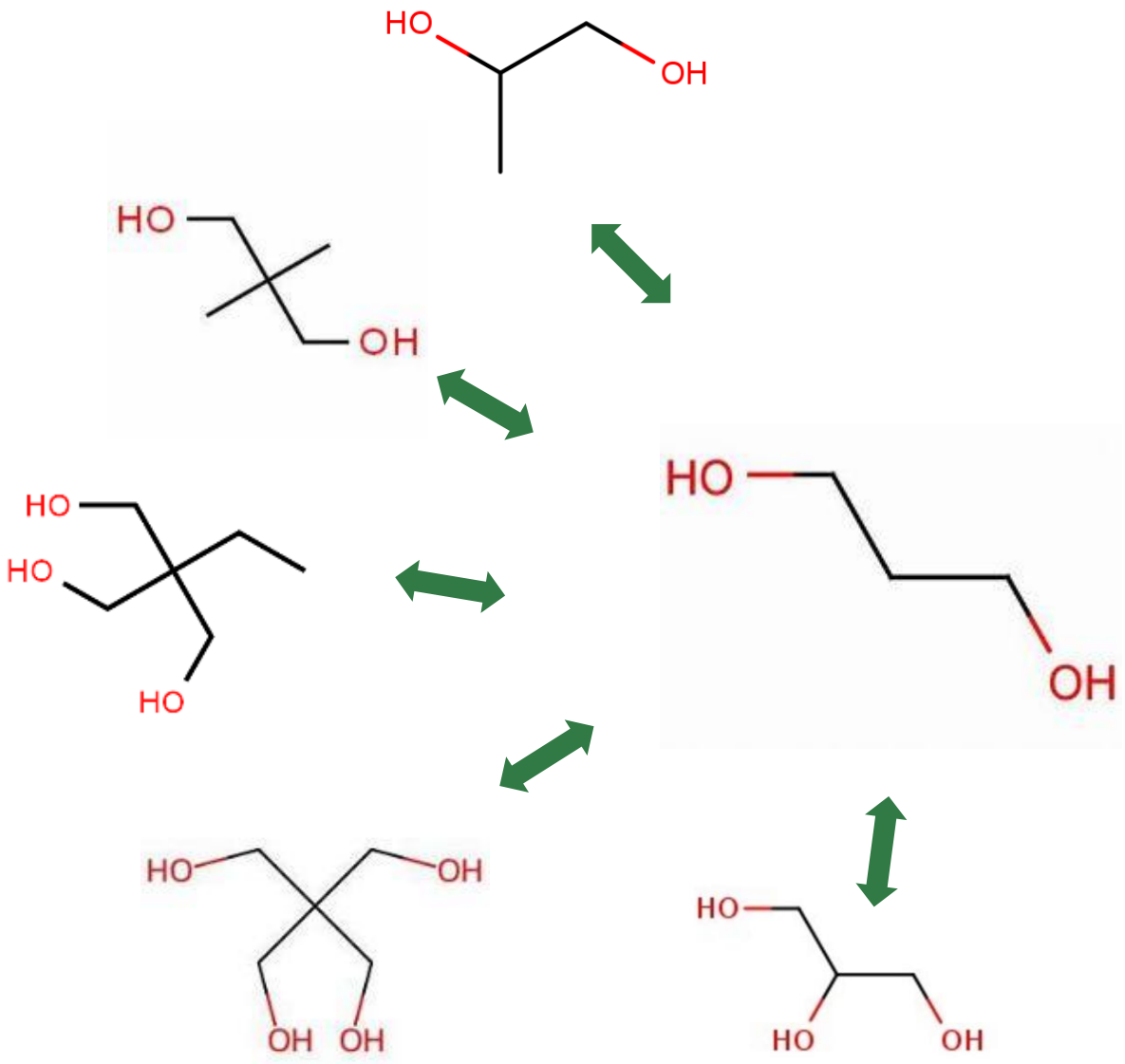




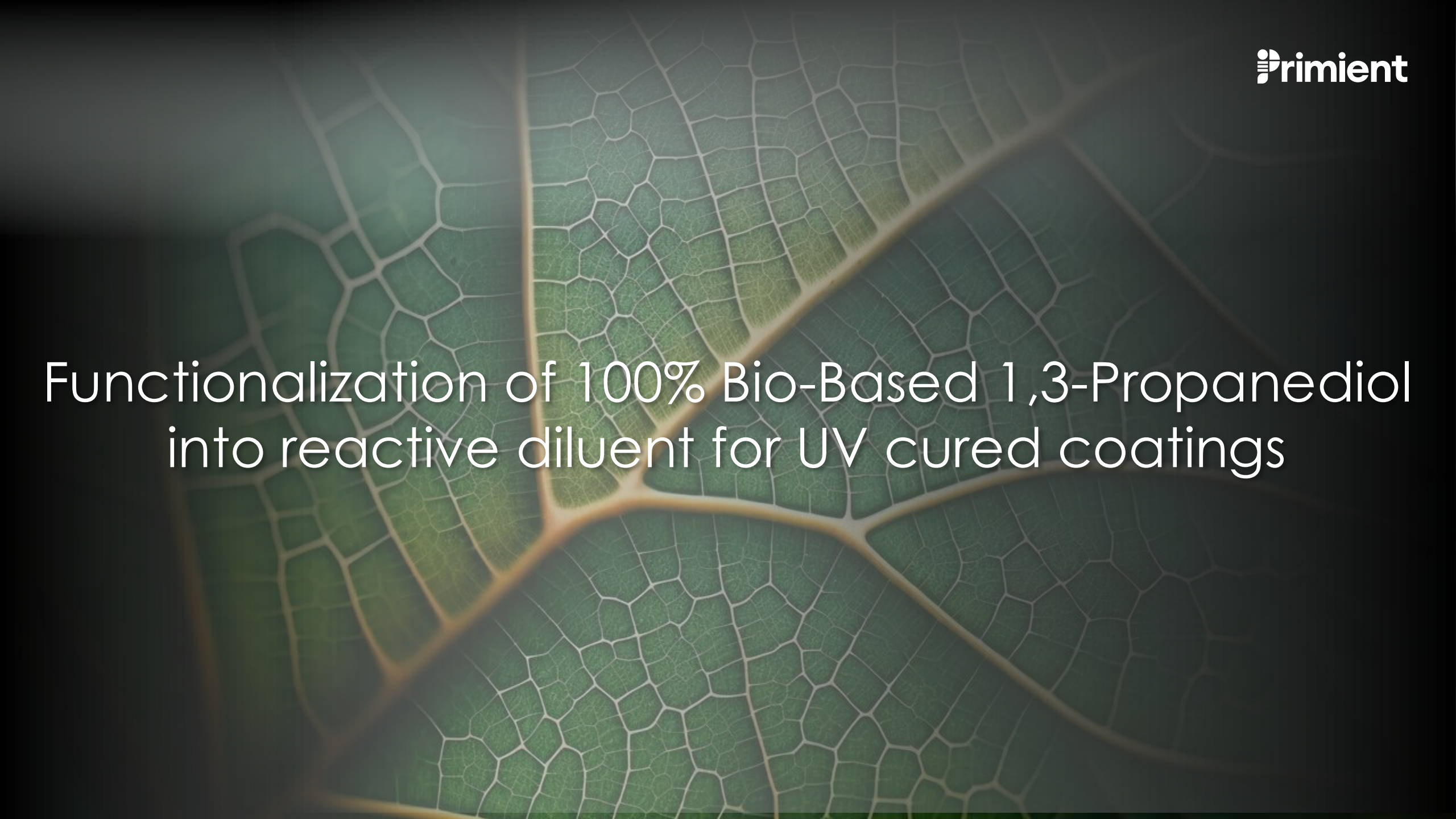




Susterra® 1,3-Propanediol as Building block

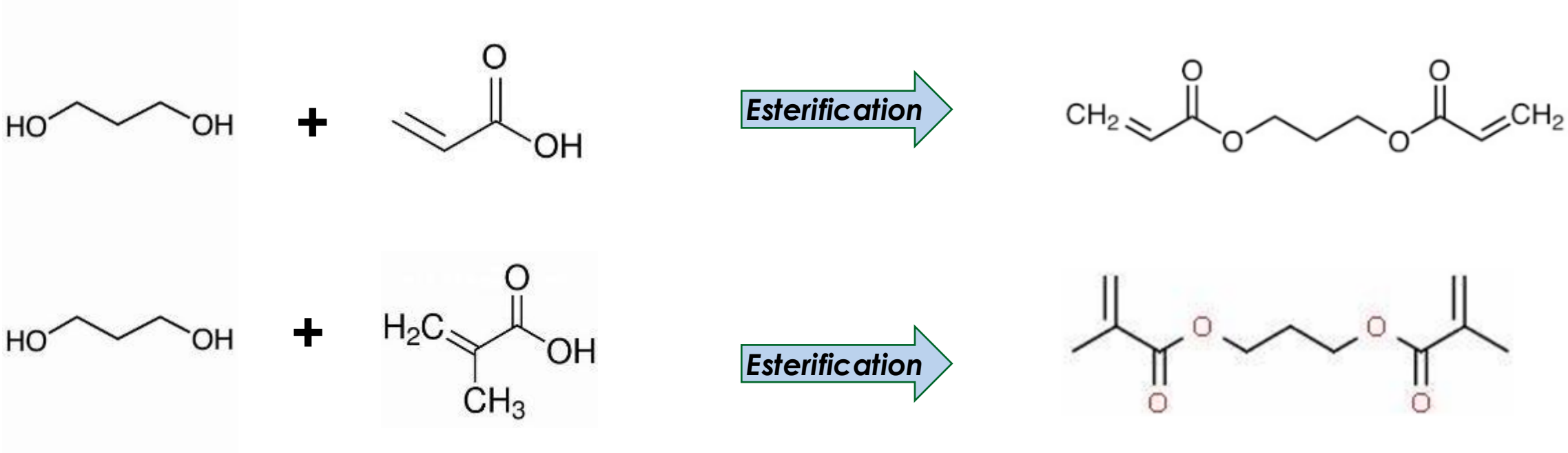


- **Partly or fully replacement depending on the functionality and application**
- **Polyester (Alkyds, powder, coil and can)**
- **Polyether**
- **Polycarbonate diols**
- **Polyurethane**



Functionalization of 100% Bio-Based 1,3-Propanediol into reactive diluent for UV cured coatings

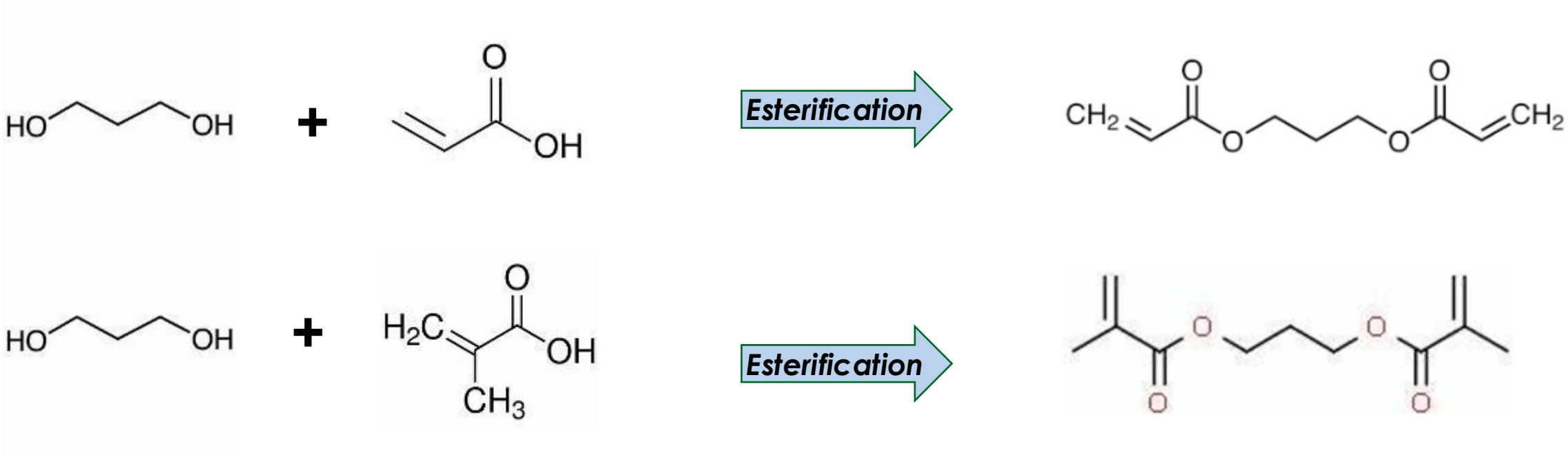
Bio-PDO Di-acrylates and Di-methacrylates



Re-esterification of ethyl-acrylate was possible, but stability issues appeared upon storage. That route needs further tests.

Re-esterification of methyl methacrylate was also tested and confirmed possible. However, conversions was lower than the esterification process. Re-esterification need longer reaction time.

Bio-PDO Di-acrylates and Di-methacrylates



PDDA and PDDMA was tested in a very simple recipe for comparison to BDDA

	% for acrylate
GENOMER® 4215 (Acrylate resin)	48.5
Diol Diacrylate (Reactive diluent)	48.5
GENOCURE® LTM (Photo initiator)	3

Bio-PDO Di acrylates: Film Properties Results and Observations Compared to BDDA

Higher Reactivity: 1,3-PDO diacrylates generates higher reactivity, which makes it possible to formulate with less.

Hardnes and impact resistance: 1,3-PDO diacrylates generates harder film and improved impact resistance, revealing flexible film. Improved Cross-link density?

Improved chemical resistance: 1,3-PDO diacrylates improve the chemical resistance which is crucial for industrial wood coating applications. Furniture, kitchen interiors, etc.

Carbon Footprint reduction and renewable content: 1,3-PDO improves the performance of the UV coating and generates a sustainable option for any producers who wants to improve the LCA, including carbon footprint.







Functionalization of 100% Bio-Based 1,3-Propanediol into reactive diluent for UV cured coatings

PDDMA and PO3GDA in an Extensive Study

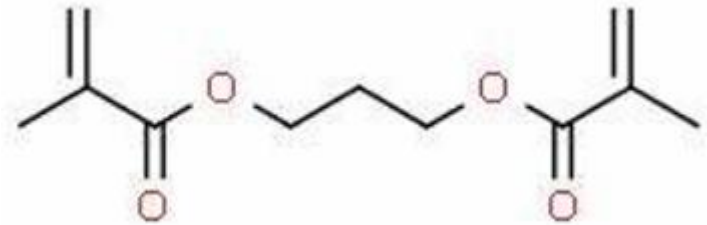
Preparation and properties of new UV-curable coatings synthesized using bio-based 1,3-propanediol

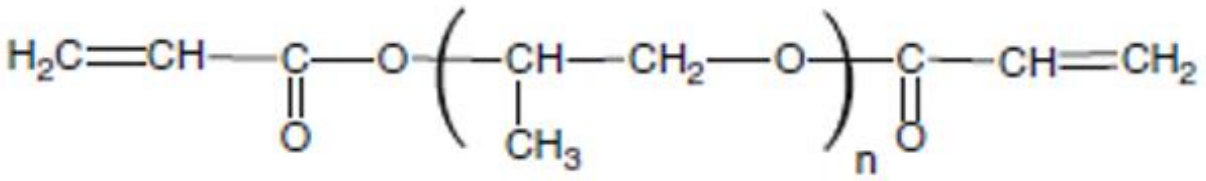
Michael Shen [a], W. Curtis Anderson Jr. [a], Tianxiang Chen [b], Yun Zhu [b], Guiyou Wang [b]

PDDMA and PO3GDA

Scope: Functionalize 1,3-PDO and its polyether, PO3G, with di-methacrylate and di-acrylate respectively. Ending up in reactive diluents for UV coating; And used as reactive diluents with Polyurethane Acrylates (PUA) Oligomers. And as building block in the PUA

WHY: Odd three carbon chemistry are from technical point of view an additional difunctional chemistry of interest to add to any product portfolio of reactive diluent. Provide new technical properties and benefits; And one of the few biobased reactive diluents on the market.



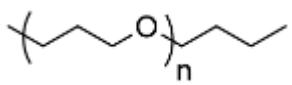


- **Reaction of PDO with acryloyl chloride (e.g. US 4,522,913)**

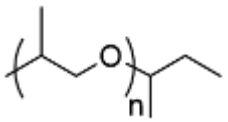
Polyurethane Acrylates, PUA

All PUA was based on polyether or polyester. In this study following was used:

- **PO3G-2000**

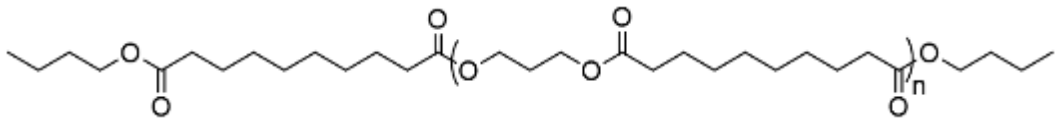


- **PPG-2000**

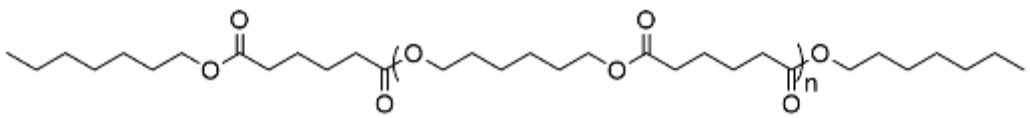


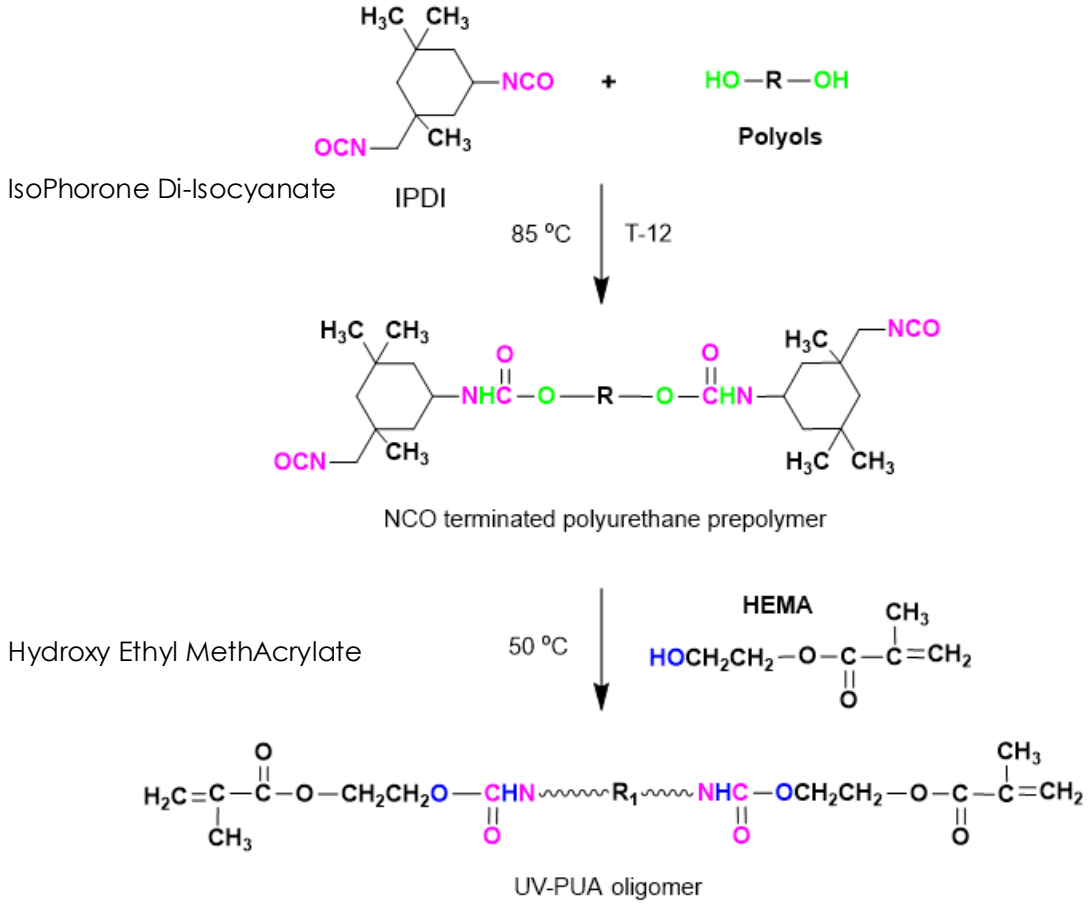
1,3-PDO

- **PPSe-2000**



- **PHA-2000**





Preparation of UV cured coatings

PUA Oligomers **70%**

Reactive diluents: **30%**

Darocur 1173 **3% on total mass**



Parameters of the bio-based reactive diluents

Samples	M_n (g/mol)	Viscosity@25 °C (mPa·s)	C = C content (mmol/g)	Bio-content (%)
1,3-PDODMA	212.1049	3.01	9.43	27.1
PO3GDA	358.1991	9.27	5.64	66.7

Different in Properties of PUA Oligomers based on PO3G versus PPG

1,3-PDO



Property	**PO3G-PUA**	**PPG-PUA**
Viscosity	Low	Lowest
Flexibility	High	Lower
Stiff/Hard (Dry film)	Highest	High
Solvent Resistant	Very good	Good
Water resistant	Very good	Good
Chemical Resistant	Very good	Good
Mechanical Properties	Very good	Good
Gloss	Very good	Good



Polyester Better

Different in Properties of 2K PUA resin diluted and cured by PDODMA versus PO3GDA

Property	PDODMA	PO3GDA
Viscosity	Lowest	Low
Cross-linking density	Highest	High
Solvent Resistant	Better	Good
Water resistant	highest	High
Chemical Resistant	Better	Good
Mechanical Properties	Better	Good
REACH	Yes	No

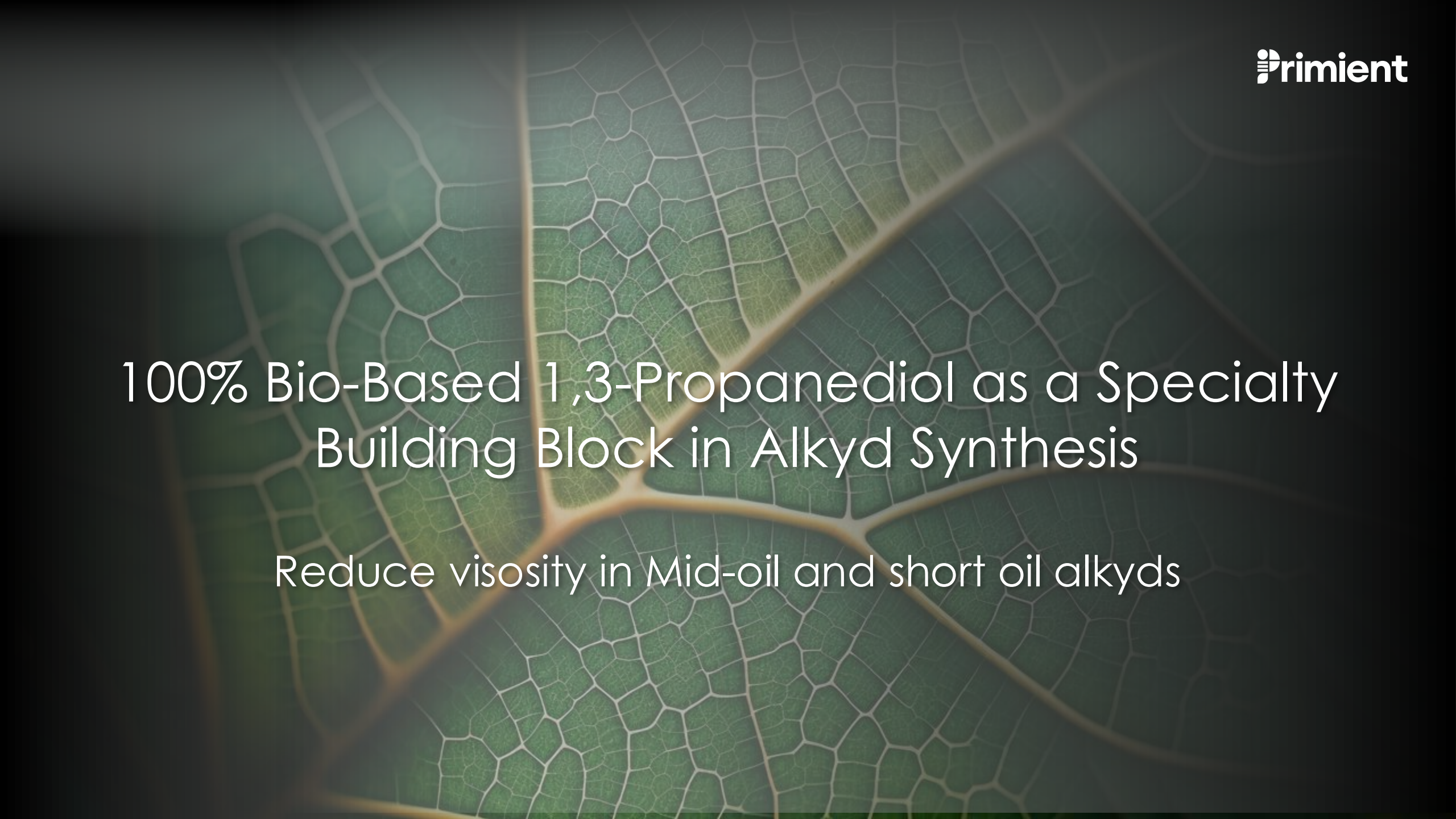
Improved technical performances using bio based 1,3-PDO

Reducing GHG emissions (scope 3): **1,3-PDO and PO3G is sustainable choice to functionalize into reactive diluents to improve the LCA and reduce the carbon footprint of any coatings.**

Using polyester or polyether based on 1,3-PDO we can generate a up to 74% bio-based 2K-PUA, with better performances than corresponding classic fossil based.

Reduced viscosity combined with improved technical properties: **1,3-PDO and PO3G improves the performance of the PUA-2K based coating, both as functionalized reactive diluents and as building block in the backbone prepolymers (as a polyether or polyester).**

Functionalized PO3G is an interesting solution since no REACH registration is necessary due to the polymeric character.



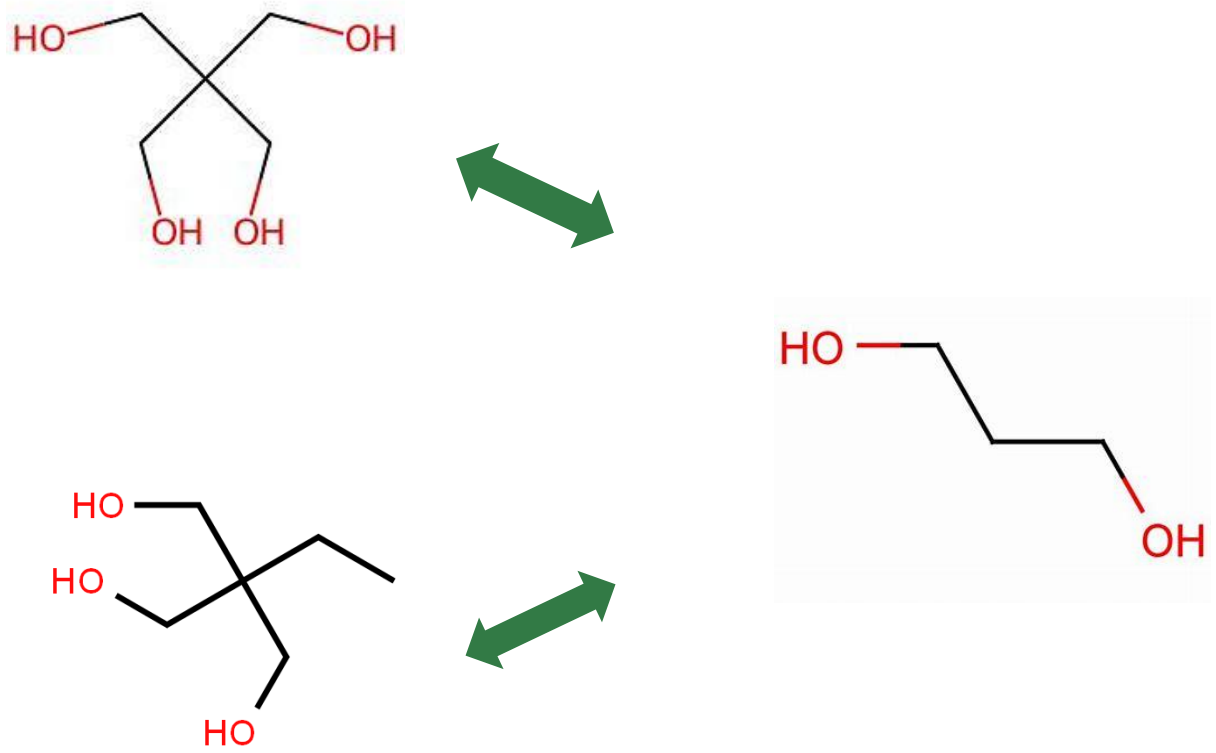
100% Bio-Based 1,3-Propanediol as a Specialty Building Block in Alkyd Synthesis

Reduce visosity in Mid-oil and short oil alkyds

Mid and Short Oil Alkyds

Scope: Partly Replace Penta with 1,3-PDO in a mid-oil alkyd (50%).

Desired outcome: Achieving backbone flexibility, which in turn will lower the viscosity, providing VOC (volatile organic compound) system reduction for standard solvent borne alkyds and/or facilitating the emulsification process for water borne alkyds.



Synthesis mid oil
TOFA (Tall oil fatty acid)
Phthalic anhydride
Benzoic acid
PENTA (pentaerythritol)
1,3 – PDO (1,3 – propanediol)

Synthesis short oil
Isononanoic acid (synthetic)
Phthalic anhydride
Benzoic acid
Trimethylolpropane (TMP)
1,3 – PDO (1,3 – propanediol)

Mid and Short Oil Alkyd Synthesis

Mid Oil Alkyd: Up to 5% replacement of Penta erythritol

		PDO-0	PDM-1	PDM-3	PDM-5
Pentaerythritol replacement by PDO	**molar**	**0**	**1%**	**3%**	**5%**
	weight	**0**	**1.1%**	**3.3%**	**5.6%**
Raw materials weight (g)		1068.7	1069.3	1069.9	1070.5
Condensation water (g)		71.5	71.5	71.5	71.5
Max conversion (g)		997.2	997.8	998.4	999.0
k_P (Patton constant)		1.0160	1.0196	1.0261	1.0326
R (Ratio eq. OH/COOH)		1.296	1.297	1.297	1.297
OL (Oil length)		0.51	0.51	0.51	0.51
ΔOH (Eq. difference between OH and COOH expressed in mg KOH/g)		95.49	95.90	95.85	95.79
Reaction time fusion/azeotr.		7 h	8+8 h	7+8 h	6+9 h
Max. temperature		230-240°C	230°C	230°C	230°C
Solids 2 h/130°C (%)		96.8	97.1	96.7	97.1
Viscosity Brookfield **70°C**(mPa.s) 100 rpm		34 160 (Sp6)	37 560 (Sp6)	21 080 (Sp6)	15 180 (Sp6)
Acid value (mg KOH/g)		8.2	8.2	8.7	10.3
Hydroxyl value (mg KOH/g)		96.2	92.9	94.8	99.4
Dilution		**xylen**	**xylen**	**xylen**	**xylen**
Solids 2 h/130°C (%)		66.9	67.0	67.1	67.2
Viscosity Brookfield 25°C (mPa.s) 100 rpm		3 052 (Sp4)	3 530 (Sp4)	2 660 (Sp4)	1 620 (Sp1)
Mn		2 700	2 900	2 900	2 400
Mw		20 900	25 300	17 600	11 700
Polydispersity		7.71	8.64	6.07	4.82

Short Oil Alkyd: Up to 25% replacement of Trimethylol Propane

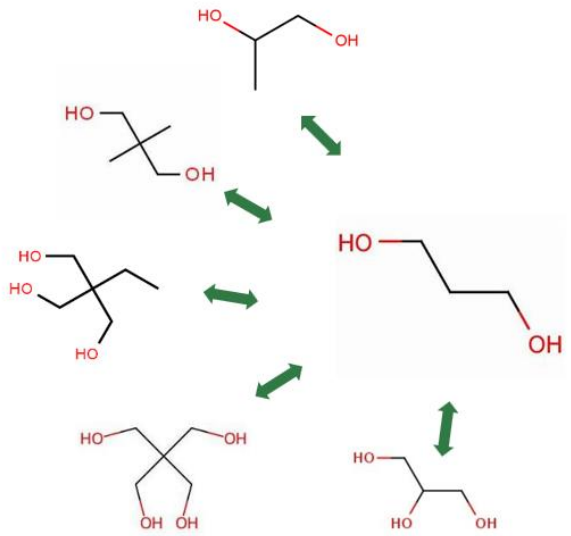
		PSO-0-2	PSO-5-2	PSO-10-2	PSO-15-2	PSO-20-2
Trimethylolpropane replacement by PDO	molar	0	5%	10%	15%	20%
	weight	0	4.3%	8.6%	13.1%	17.5%
Raw materials weight (g)		1048.0	1045.0	1042.0	1038.9	1035.9
Condensation water (g)		76.0	76.0	76.0	76.0	76.0
Max conversion (g)		972.0	969.0	966.0	962.9	959.9
k_P (Patton constant)		1.0495	1.0605	1.0715	1.0825	1.0935
R (Ratio eq. OH/COOH)		1.319	1.319	1.319	1.319	1.319
OL (Oil length)		0.258	0.259	0.260	0.261	0.261
ΔOH (Eq. difference between OH and COOH expressed in mg KOH/g)		127.63	128.06	128.47	128.88	129.30
Reaction time fusion/azeotr.		6 h	8.5 + 6.5 h	8.5 + 6.5 h	8.5 + 6.5 h	8.5 + 6.5 h
Solids 2 h/130°C (%)		97.2	97.7	97.1	96.9	96.7
Viscosity (mPa.s) **100°C** 100 rpm, Sp5		9 110	8 600	5 160	3 240	2 150
Acid value (mg KOH/g)		7.1	6.6	7.1	6.5	7.4
Hydroxyl value (mg KOH/g)		124.9	119.5	122.6	119.2	126.2
Dilution		**xylene**	**xylene**	**xylene**	**xylene**	**xylene**
Solids 2 h/130°C (%)		65.5	65.5	65.5	64.7	65.5
Viscosity Brookfield 25°C 100 rpm, Sp4 (mPa.s)		1 260	1 070	770	590 (Sp1)	484 (Sp1)
Color		4.1	4.6	4.2	5.0	4.3
Mn		1 800	1 700	1 500	1 500	1 500
Mw		5 200	4 300	3 600	3 100	3 000
Polydispersity		2.84	2.47	2.40	2.08	1.98

- **Viscosity decreased with increasing the amount of PDO**

Mid and Short Oil Alkyds

Mid Oil Alkyd:

- Viscosity decreased with increasing the amount of PDO (except for PDM-1)
- Drying prolonged at 4% and above. But 3 % is good enough for lower viscosity.
- QUV after full drying revealed no compromises on the film properties.
- Alkyd for emulsions there are no compromises!



Short Oil Alkyd:

- Two systems: Melamine cured stoving enamel and 2K PUR (isocyanate)
- Viscosity decreased with increasing the amount of PDO
- Drying slightly prolonged at 20 to 30%, but basically no issue.
- Hardness slightly reduced with increased PDO for stoving enamel but not for the 2K PUR. (Acceleraiton)
- MEK, Chemical resistance as good or better.
- Increased Flexiblity in dry film.
- Significant savings in VOC



Short Oil alkyds

Stoving Paint (Melamine hardener)

Compound	Amount (g)
Short oil alkyd Susterra PSO-0 to PSO-30 (65% in xylen)	44.66
Byk 1760 (defoamer)	0.74
Disperbyk 110 (dispersant)	0.89
Kronos 2160 (titanium dioxide)	37.21
Xylen/Butanol 2:1	4.77
Cymel 303 (melamine crosslinker)	11.16
Cycat 4040 (catalyst)	0.56
Total	**100**

TS: 78.8% PVC: 20.1 Q: 35.3

Stoving Paint			
Sample	**Viscosity after 4 days (mPas)**	**VOC (g/l) after dilution to viscosity ~200 mPas**	**Decrease in VOC**
PSCS-0	725	380	/
PSCS-10	430	325	14%
PSCS-20	340	320	16%
PSCS-30	200	265	30%

Solvent-xylen

2K PUR Paint (Isocyanate)

Compound	Amount (g)
Short oil alkyd Susterra PSO-0 to PSO-20 (70% in xylen)	58.13
Byk 1760 (defoamer)	0.76
Disperbyk 110 (dispersant)	0.61
Byk 333 (surface additive)	1.00
Kronos 2160 (titanium dioxide)	28.40
Dabco T-12 CL 10% (catalyst)	0.20
Desmodur N3900 (isocyanate hardener)	10.90
Total	**100**

TS: 75.1 % PVC: 14.2 Q: 24.9

2K PUR Paint			
Sample	**Viscosity after 4 days (mPas)**	**VOC (g/l) after dilution to viscosity ~2 720 mPas**	**Decrease in VOC**
PSCP-0	7 250	280	/
PSCP-5	7 050	275	2%
PSCP-10	4 870	260	7%
PSCP-15	3 630	245	12%
PSCP-20	2 720	235	16%

Solvent-xylen

Summary Alkyd Resins

Lowering VOC: Replacing Penta (short oil) and TMP (mid oil) with 1,3-PDO lower the viscosity of the alkyd, which means that less VOC can be used in the final resin/coating.

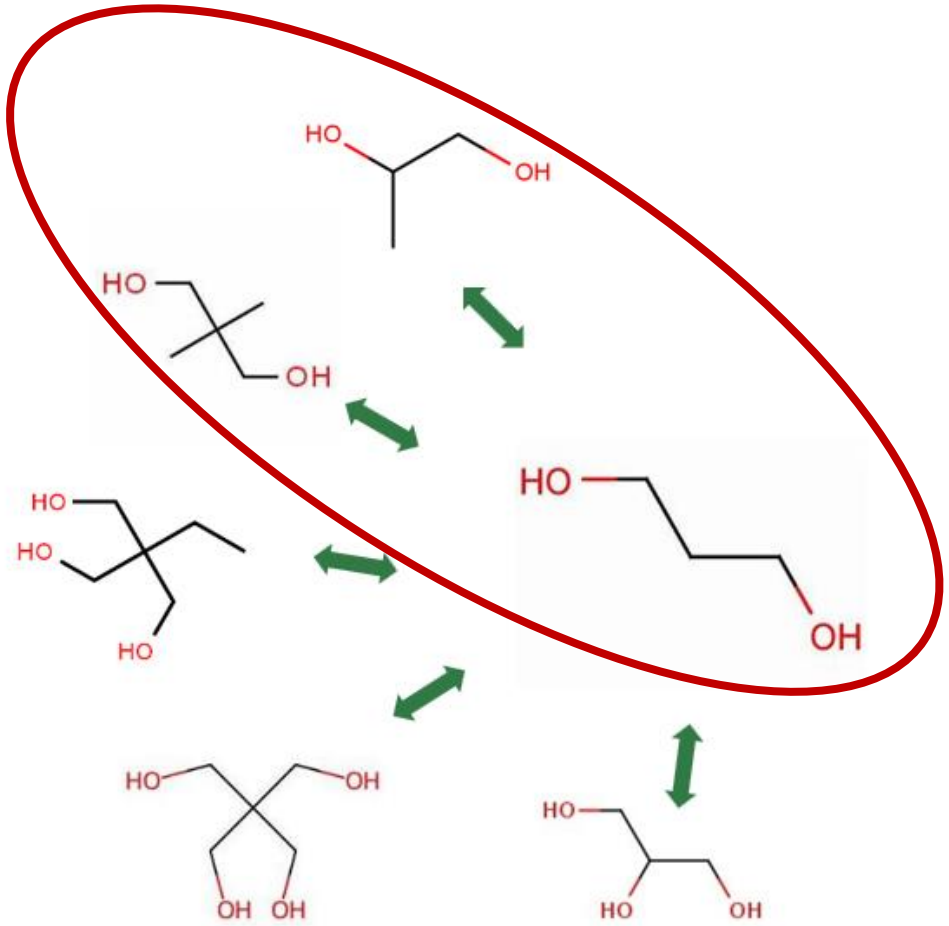
Easier emulsification: Alkyd made by 1,3-PDO can easier be emulsified due to lower viscosity. 1,3-PDO simplifies the emulsion process. Less energy can be used in the process. Shorter oil alkyds can be processed into emulsions.

Flexibility improvement: 1,3-PDO improves the flexibility of the alkyd both from performance and processing point of view, without compromising on cost and quality.

Lowering GHG emissions (scope 3): Using the 1,3-PDO in the alkyd generates a lower carbon footprint and increase the biobased content.

Polyesters

- **No compromises with the functionality**
- **Lowering viscosity**
- **Avoiding Adipic acid**
- **Cheaper formulation**
- **Simpler process (Can pre-dilute NPG)**



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Thanks to synpo

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Global Market Development Manager

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October 28 2026, Milan Paints & Coatings