

Energy Curable Oligomers for Exterior Building Products

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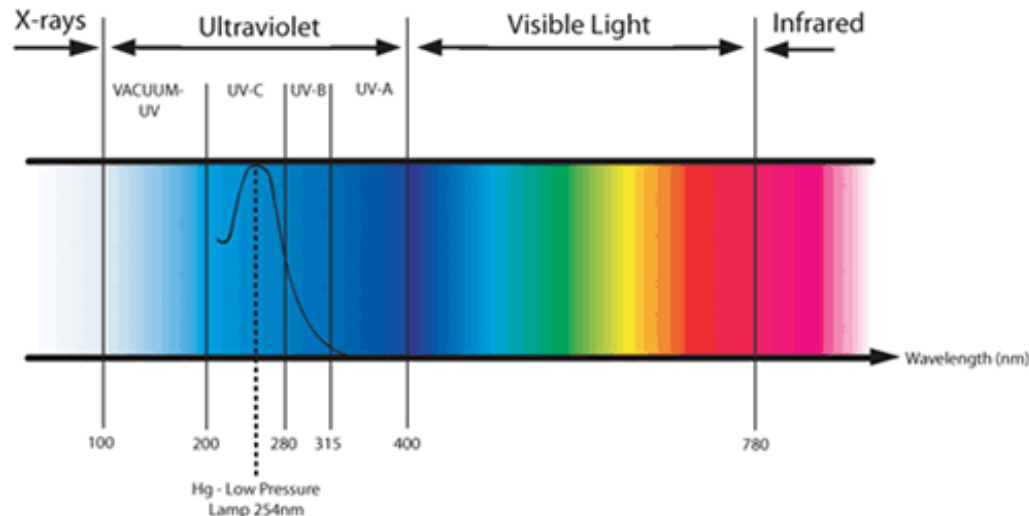


Background

What is Ultra-Violet (UV) curing?

- Using UV energy or visible light, as opposed to heat, solvent evaporation, or oxidation (air-drying), to convert a liquid formulation into a solid material
- Types of energy used:
 - Ultra Violet (UV): 200 – 400 nm
 - Visible light: typically 380 - 450 nm

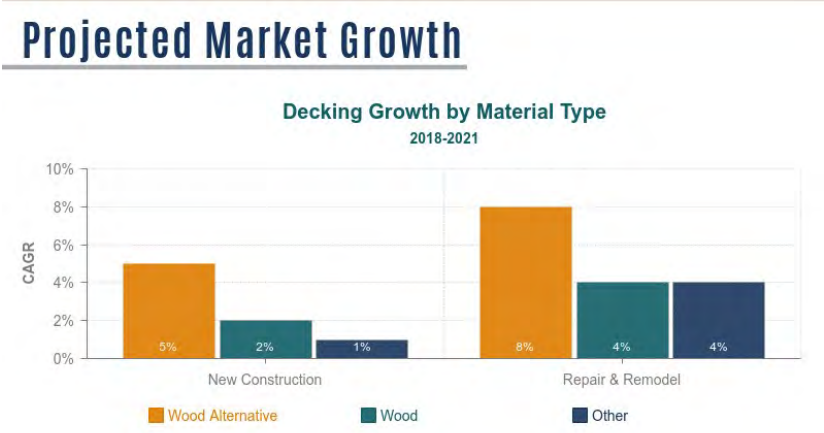
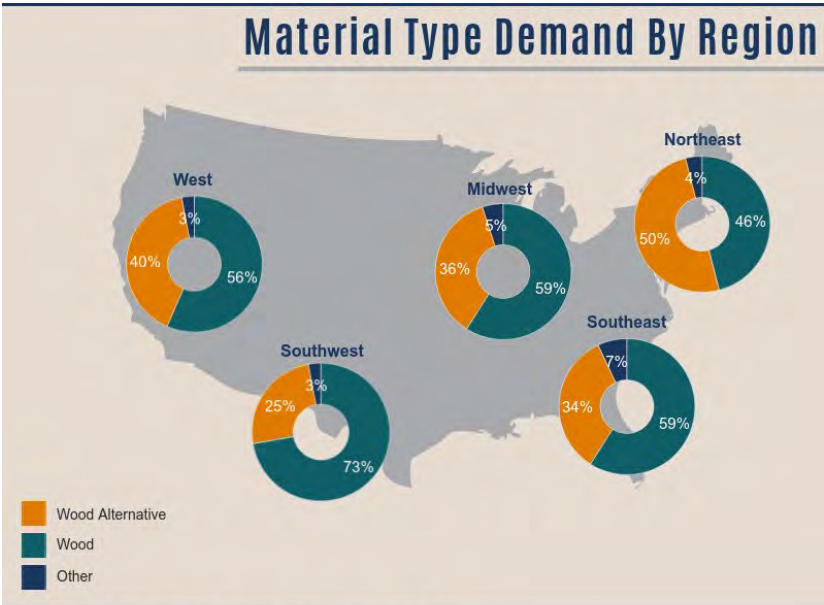
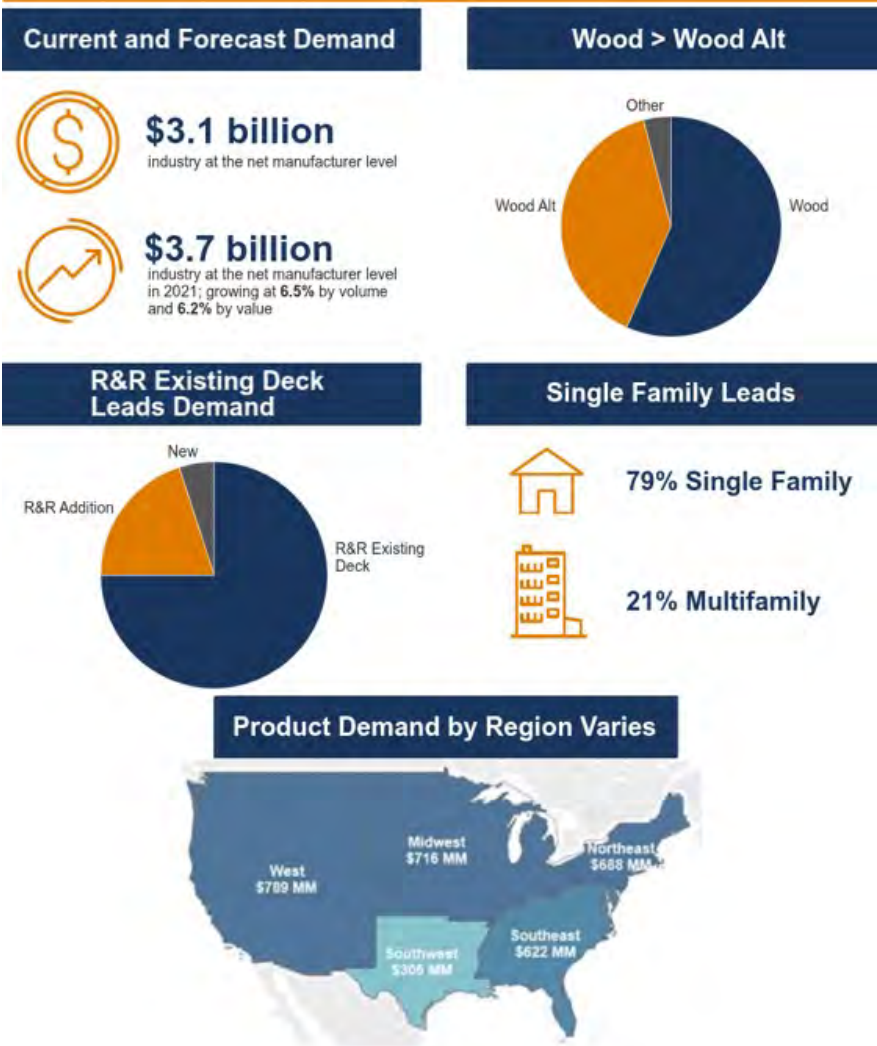
ELECTROMAGNETIC SPECTRUM



Advantages of 100% Solids UV Curable Systems

- Productivity, Productivity, Productivity
 - Seconds to cure vs. minutes or hours
- Lower Overall Cost (per cured part)
 - 100% solids, cure speed, recycling of coating, etc.
- Single component formulas
 - Eliminates mixing errors found in 2 component systems
- Regulatory Concerns (VOC emission)
 - Avoid solvent use in most cases
- Smaller equipment footprint
 - Less floor space needed
- Energy costs

Residential decking – NAM market overview



Source: Principia’s US Residential decking market at a glance

Residential decking – Market trends

- The housing and renovation market rebounded, driving growth on decking
- Outdoor entertaining is increasing, leading to expansion and decking upgrade;
 - Customization; New materials, colors, texture and haptics
 - Multi-usage; kitchens, fish ponds, pools, ...
 - Added value at home resale
- Durability is stimulating interest in hardwood and (capped) composites;
 - 2012 - 2016: 5.5% increased sales in composites, while only 3.8% for wood
- Lighter colors are still prevailing, but dark and exotic looks are increasing
- Warranties are a selling proposition for composites; lifetime, stain, fade, labor warranties
- Sustainability is still not a major driver, but nice to have
- Home builders still prefer wood, while contractors for renovations are getting used to composite.
- Ability to compete for decking producers is also defined by providing a one stop shop.

Residential Decking – PT wood vs. composites

SUMMARY TABLE						
DECKING DEMAND BY MATERIAL TYPE & MARKET (million lineal feet)						
Item	2001	2006	2011	2016	% Annual Growth	
Decking Demand	2946	3266	3645	4120	2.1	2.2
By Material Type:						
Wood	2645	2705	2660	2570	0.4	-0.3
Wood-Plastic Composite	242	456	825	1315	13.5	12.6
Plastic & Other	59	105	160	235	12.2	8.8
By Market:						
Residential Buildings	1802	2078	2305	2615	2.9	2.1
Nonresidential Buildings	282	280	350	405	-0.1	4.6
Nonbuilding Construction	862	908	990	1100	1.0	1.7
\$/lineal foot	1.23	1.40	1.53	1.83	2.6	1.8
Decking Demand (mil \$)	3611	4583	5585	7520	4.9	4.0

Source: The Freedonia Group Inc.

NORTH AMERICAN RESIDENTIAL DECKING DEMAND

(in \$ millions, manufacturer pricing)

	2013	2014	2015	2016*
WOOD	1,310	1,380	1,400	1,460
SYNTHETICS	860	900	910	970
OTHER	10	10	10	10
TOTAL	2,180	2,290	2,320	2,440

* FORECAST

Source: Principia, 2016

The deck market continues to rebound from the recession years, with synthetic products growing at a faster rate but treated-wood decks still maintaining a significant majority.

Source: LBM Journal: IN DEPTH: Decks

Top three reasons why homeowners who considered wood alternative decking products but did not purchase:

- 1 > High material cost
- 2 > Preference for natural wood or more familiar with wood
- 3 > Unsure about wood alternative quality & performance

Top three reasons why homeowners who, if forced to start over and replace the deck, would choose something other than wood:

- 1 > Frequent staining or treating
- 2 > Frequent pressure washing
- 3 > Splintering & Warping

Source: Principia's US Residential decking market at a glance

Exterior Decking – Substrates and coating tech.

Pressure Treated (PT) Lumber

- Today's no 1 decking material
- Affordable and easy to apply
- Chem. treated milled Southern Pine
- 2 x 6 (90 cents/ft)&2 x 4 (60 cents/ft)
- Dimensionally unstable
- Routine maintenance is necessary
 - Annual power washing
 - Bi-annual surface treatment



Natural wood

- Redwood and Cedar
- Rich in color and natural beauty
- Tannins and oils as natural resistance
- Heart vs. Sapwood
- 3 times the price of PT wood
- 2 x 6 (approx. 3 to 4 USD/ft)
- Routine maintenance is necessary
 - Annual power washing
 - Triannual surface treatment
 - Stain to be applied



Tropical Hardwood

- Extremely hard, durable & resistant
- Heavy and difficult to cut
- Similar cost to redwood/cedar
- 1 x 6 (3.5 USD/ft)
- Oi based stain or UV block is necessary

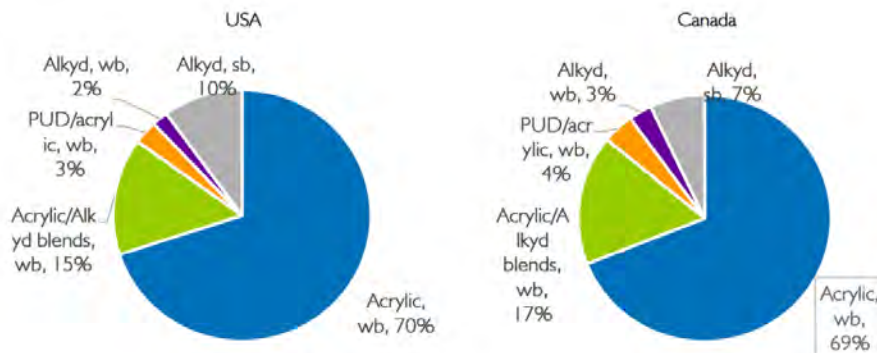


Composites

- Composites + plastic lumber
- Polyethylene & PVC are most frequent
- Wood fibers and recycled plastics
- High weather resistance
- Good stain resistance
- Less subj. to rot, split, splinter & warp
- 2 x 4, 2 x 6 and 5/4 x 6
- 2.5 USD/ft for composites
- 3 USD/ft for plastic lumber
- Low maintenance (no stain/finish)



Exterior siding wood coating technologies



- ❑ Wood deck: annual wash with a light organic solvent preservative
- ❑ For greater level of protection or color, similar stains than for siding.
- ❑ Other potential decking materials; fiber cement, aluminium, ...
- ❑ Trends;
 - Ease of use: less substrate preparation & one coat finishes
 - WB lower ambient drying temperatures
 - Lower VOC content (cf. co-solvent)
 - Durability and color retention, reducing maintenance

Residential Siding – NAM market overview

Current and Forecast Demand

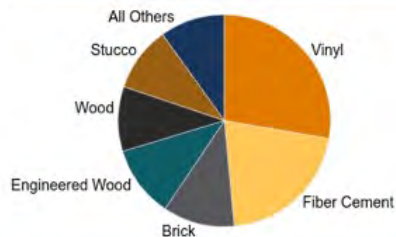


63 Million Squares
market volume in 2018



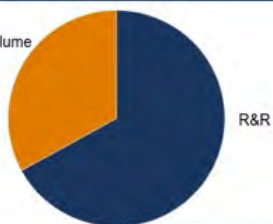
3.5% Growth Rate
projected in volume through 2021

Vinyl Leads



Siding Replacement Drives Demand

New by volume



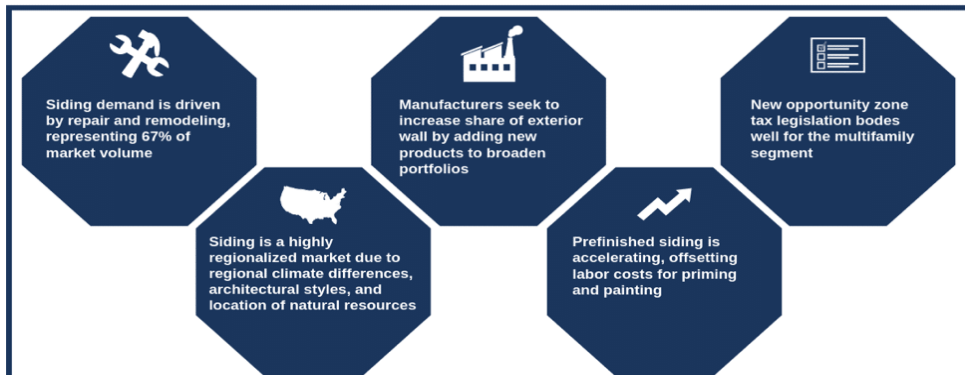
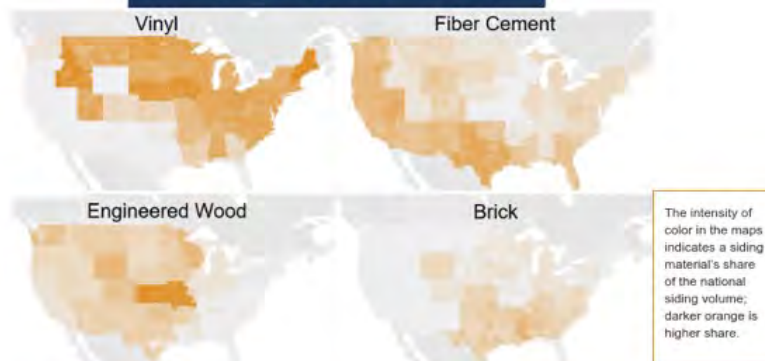
Single Family Leads



80% Single Family

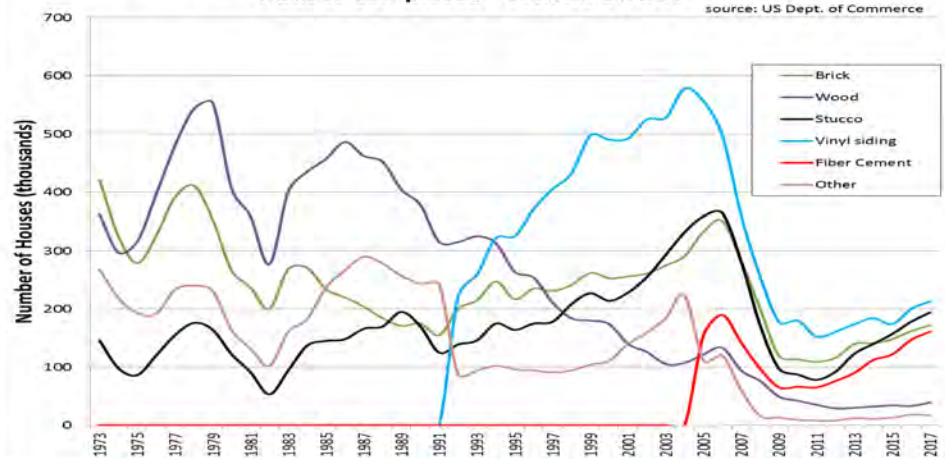
20% Multifamily

Highly Regional Market



Primary Type of Exterior Wall Material of New Single-Family Houses Completed - UNITED STATES

source: US Dept. of Commerce



- ☐ US residential siding market is expected to reach 8.2 bUSD by 2021
- ☐ New construction but more remodeling & renovation drives growth
- ☐ People are looking to increase the curb appeal of their homes
- ☐ Average age of siding between 13 and 16 years, lower than recently
- ☐ Some state law dictate color and materials, but pressure to change

Source: Principia's US Residential siding market at a glance

Exterior Siding – Substrates and coating tech.

Vinyl

- Many style and color options
- Easy to install
- Moisture and insect resistant
- Good fire rating (although melting)
- Reduced fading with new tech.
- Very low maintenance
- Brittleness and cracking with age
- Falls short of genuine wood look
- Warranty of 25 yr (lifespan ~ 30yr)
- Few recycling companies



Fibre cement & Engineered wood

- Lifespan of up to 50 years
- Wood look at low cost & maintenance
- Class A fire rating
- Resist insect, mold and rot
- Wide style options (less than vinyl)
- To be painted
- Absorbs moisture if core is exposed
- Scratches are visible
- Fiber cement hard to cut + forms dust
- Not recyclable



Wood

- Customization of look
- Lifetime siding if maintained
- Green and sustainable
- Excellent curb appeal & market ROI
- To paint or stain every 3 – 5 years
- Subject to insect and moisture damage
- Poor fire rating

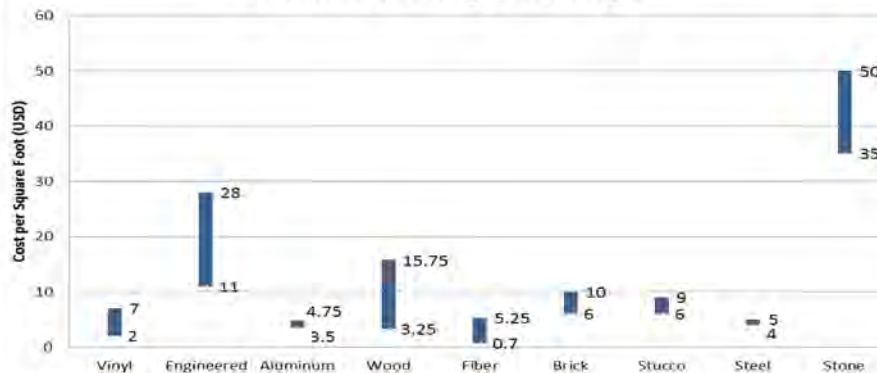


Stucco & EIFS

- Good appearance and curb appeal
- Design freedom
- Lifetime siding when maintained
- Resistant to insect and fire
- Higher maintenance and repair costs
- Subject to moisture damage
- Cracking at house settling/shifting



US Exterior Siding Cost Ranges



Source: HOMEADVISOR

- ❑ Home owners are looking for product upgrade and aesthetics
- ❑ Increased customization; color, texture and aesthetics
- ❑ Darker colors; grey and black are trending (challenge for temp.)
- ❑ Smoother surfaces above grainy look (challenge to vinyl)
- ❑ High durability, water drainage, low maintenance & fading are key
- ❑ Warranties can affect consumer choices
- ❑ Home owners can accept higher prices, while builders not
- ❑ PVC trims are gaining interest for high end markets
- ❑ Prefab/Preprimed panels combined with ease of use are attractive
- ❑ Sustainability gains is interest, but is more a "nice to have"
- ❑ Fire retardancy remains an important factor

Source: Info PRA world: Architectural coatings for wood America's

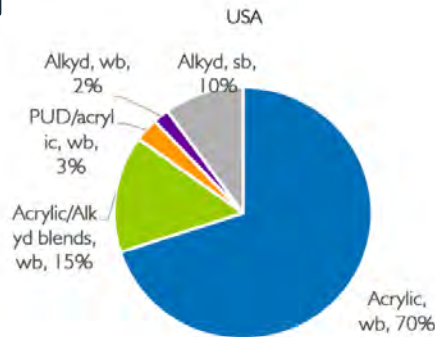
Exterior siding – Coating technologies (wood & fiber cement)

Exterior wood siding

Clear or pigmented WB acrylic/alkyd



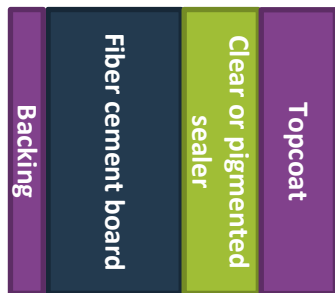
WB acrylic or PU dispersion



- ☐ Softwood plywood, hardwood and engineered wood
 - ☐ Hardwood is losing share (moisture damage)
 - ☐ Impregnated, primed and initial coat in industrial production
- OR
- ☐ Fully coated and pre-assembled in industrial processes
 - ☐ Films & foils are used for patterns
 - ☐ Blocking resistance is key (storage and stacking)
 - ☐ Application vacuum coater or spraying
 - ☐ Louisiana Pacific is the largest manufacturer
 - ☐ AkzoNobel and Valspar supply coatings for the material
 - ☐ Limited use of UV curable coatings

Exterior fiber cement siding

2k WB, WBUV or 100% UV



1kWB or WBUV

- ☐ Backing necessary for dimensional stability
- ☐ Primer used to seal porous material and hide substrate surface
- ☐ Dual cure primer can be used for better adhesion
- ☐ 80 to 85% produced with a primer applied at the plant
- ☐ 15% of the primed product received a topcoat at the factory
- ☐ Prefinished siding is growing faster
- ☐ Better weatherability is achieved with EB curing
- ☐ Big advantage is the smooth surface
- ☐ Application with roller, curtain and spray for primer, while roller for topcoat
- ☐ James Hardie is the leading supplier (85/90%), CertainTeed second and Nichiha third
- ☐ Valspar is the largest supplier of coatings for fiber cement
- ☐ PPG & SW also supply fiber cement market
- ☐ Limited use of UV curable coatings

Exterior Building Products – UV/EB curable resins value proposition

■ Addressable markets for UV/EB curable resins;

1. Factory primed/finished boards for siding & decking
Substrates: Vinyl, engineered wood, composites, fiber cement and wood
2. Exterior trim, door and window frames
Substrates: PVC and wood

■ Consumer preferences;

- Customization: design freedom, color, haptics and texture
- Low maintenance

■ Key characteristics:

- Long durability and weatherability
- Suitable for highly pigmented systems
- Adhesion to substrate
- Good water repellency
- Color retention and low color fading over time
- Flame retardancy
- High Blocking resistance
- High scratch resistance

■ Preferred chemistry:

- Aliphatic Urethan Acrylates
- Avoid resins with (aromatic & polyester backbone (cf. photodegradation))

■ Value proposition;

- 100% UV (roller): Increased process speed, low VOC, low coating thickness, high blocking resistance, substrate upgrading
- WB-UV (spray & roller): Increased process speed, low VOC, flexibility/hardness balance, easy to matt and usable in highly pigmented systems
- EB: Suitable for highly pigmented systems, good coating hardness

General Weathering – 100% solids resins

- Accelerated Weathering – Atlas Ci 4000 Xenon Weather-O-Meter

- Irradiance 0.55 W/m² – 340 nm (summer sunlight)
- Black panel temperature 75°C
- Chamber temperature 50°C
- Relative Humidity 50%
- Filters Borosilicate inner and outer
- Cycle 90 min light / 30 min light plus water

- Panel Preparation

- Formulation

Raw Material	Parts
Oligomer	70
HDDA	30
UV Absorber	3
HALS	1
Photoinitiator	5

- DFT 20u coating applied by bar coater
- Substrate Superdurable white powder coating
- Curing conditions 2 x 5m/min using 200 WPI Hg lamp

General Weathering – 100% solids resins

- Natural Weathering – Florida

- Tests were conducted in south Florida (26° N latitude) with test panels at a tilt angle of 45° from horizontal facing south.

- Panel Preparation

- Formulations

Raw Material	EB Cured	EB Cured + Stabilizers	UV Cured + Stabilizers
Oligomer	70.0	67.9	64.4
HDDA	30.0	29.1	27.6
UVA		2.0	2.0
HALS		1.0	1.0
Photoinitiator			5.0

- DFT 20u coatings applied by bar coater
- Substrate Superdurable white powder coating
- Cure Conditions EB curing – 50 kGray, 250 kev
UV curing – 2.5 m/min, 1–80 W/cm lamp

Ebecryl® oligomers for outdoor applications – typical properties

	Dilution (%)	Viscosity (mPa.s)	Functionality	Elongation at break (%)	Xenon time to crack (h)	Available location
ALUA 1	12 HDDA	2,100 (60°C)	2	36	4750	Global
ALUA 2	-	25,000 (25°C)	3.2	30	3750	Global
ALUA 3	20 HDDA	29,000 (25°C)	3.8	2	5000	Global
ALUA 4	-	30,000 (25°C)	3	3	5000	Global
ALUA 5	-	12,500 (25°C)	2	55	4000	Global
ALUA 6	20 HDDA	4,000 (60°C)	4	23	7750	Global
ALUA 7	-	2,100 (60°C)	3	50	5500	Global

Ebecryl® oligomers for outdoor applications - performance

	Property (along with weatherability)	Accelerated Weathering	Natural Weathering	
		Xenon Time to Crack (hours)	Color, Δb^* (months)	60° Gloss Retention, % (months)
ALUA 1	Good chemical resistance	4750	-0.30 (60)	88.2 (60)
ALUA 2	High flexibility	3750		
ALUA 3	Good hardness and durability	5000	-0.44 (36)	90.4 (36)
ALUA 4	Excellent surface hardness	5000		
ALUA 5	Excellent flexibility, low viscosity	4000	-1.1 (60)	94.9 (60)
ALUA 6	Best weathering	7750	-0.1 (60)	91.8 (60)
ALUA 7	Methacrylate, use as co-resin	5500		

** ASTM G155, formulation with 30 % HDDA (on total formulation) , 1 % HALS, 3 % UV absorber, 5 % MBF type PI, 20 μ DFT on white basecoated Q panel, 3200 mJ/cm² curing energy

General Weathering – WB UV resins

- Accelerated Weathering – Xenon Weather-O-Meter and QUV-A
- Panel Preparation

- Formulation

Raw Material	Parts
UV-PUD	96.5
Rheology Modifier	2.0*
Photoinitiator	1.5

* NOTE: No UVA/HALS present in the samples

- DFT 25u coating applied by bar coater
- Substrate Superdurable white powder coating or over pine
- Curing conditions Drying at 60°C for 10 minutes
30 fpm using 2 - 600 WPI Hg lamp

WB-UV for outdoor applications – UCECOAT® 7689

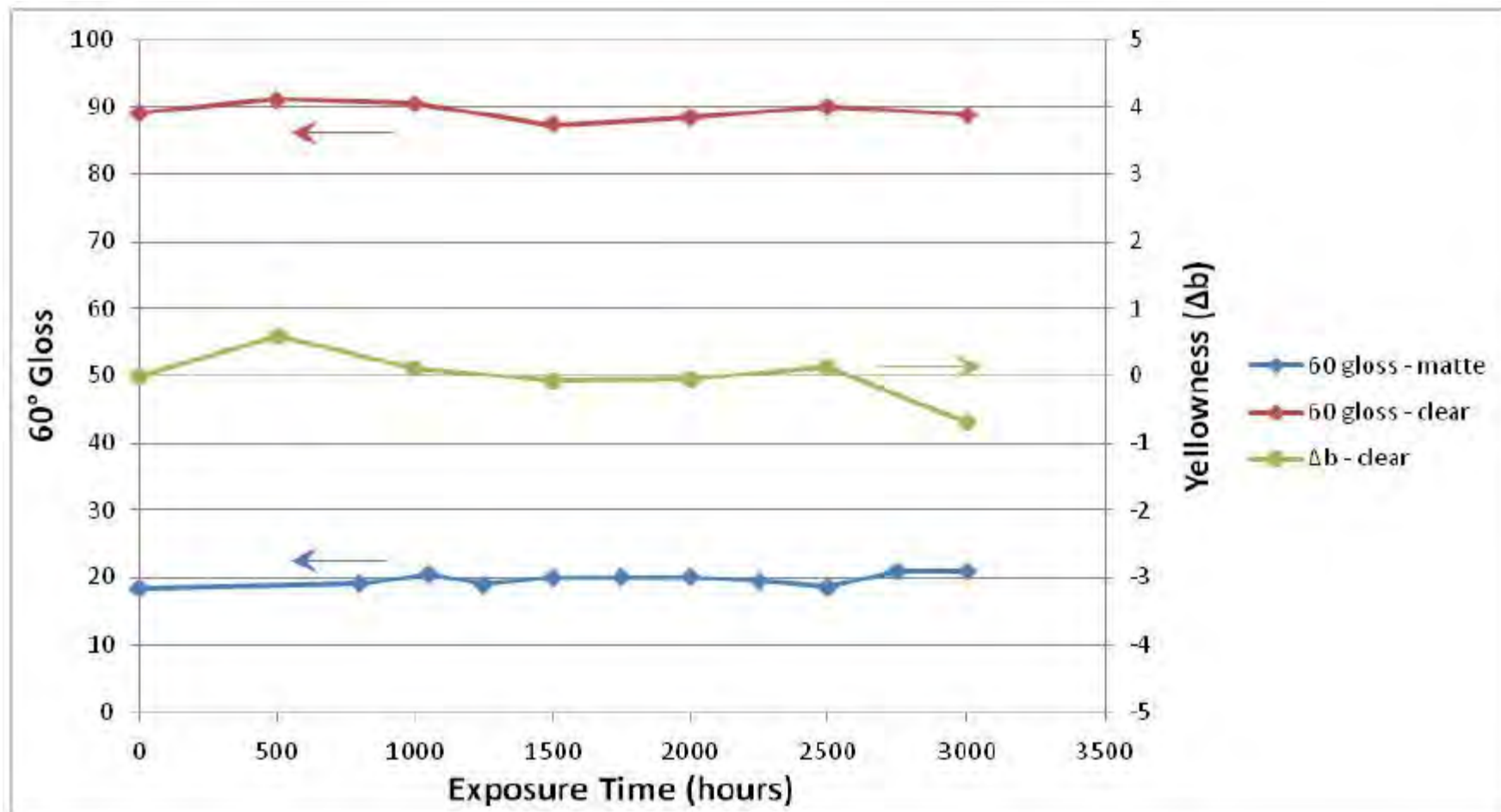
	Viscosity cP, 25°C	Solids %	pH	Particle Size nm	Tack Free Before Cure	Tg (°C)
UV-PUD 1	<200	35	7.0-8.5	<100	Yes	105

	Property (along with weatherability)	Accelerated Weathering (3000 hours XWR)		Natural Weathering (60 months FL)	
		Color, Δb^*	60° Gloss Retention, %	Color, Δb^*	60° Gloss Retention, %
UV-PUD 1	Good chemical resistance	-0.80	98.7	0.80	75

** ASTM G155, formulation is 96.5% UCECOAT, 1.5% Irgacure 500, 2.0% VXW 6360 (rheology), no UVA/HALS, 20 μ DFT on white basecoated Q panel, 1200 mJ/cm² curing energy

General Weathering – WB UV resins (UV-PUD 1)

- Color and Gloss Development – Weather-O-Meter



General Weathering – WB UV resins (UV-PUD 1)

- Color and Gloss Development – Weather-O-Meter



256 hours



2995 hours

- No film defects or gloss loss after 3000 hours Xenon arc exposure. There is some discoloration of the underlying wood since the coating contained neither UVA nor HALS.

SPF for Weatherable Coatings

Starting Point Formulation (SPF) – WB on wood

Raw Material	Function	Parts
UV-PUD 1	Oligomer, film properties	100.0
PI 3	Combination PI – long and short wavelength	2.0
Additive 1	Rheology Modifier	1.5
Silica 1	Gloss control (silica)	1.5
Wax 1	Gloss control (wax)	3.0
UVA/HALS blend	Weathering package	2.5
Additive 2	Defoamer	0.1
60 gloss		35
Cross hatch adhesion		5B
Gloss retention, % (36 months FL)		>92
Delta b (36 months FL)		<0.8

Starting Point Formulation (SPF) – WB on vinyl

Raw Material	Function	Wt. %
UV-PUD 1	Oligomer, film properties	90.7
PI 3	Combination PI – long and short wavelength	1.5
Additive 1	Rheology Modifier	0.8
Silica 1	Gloss control (silica)	3.0
UVA/HALS	Weathering package	2.5
Water	Viscosity control	10.0
60 gloss		7-8
X-hatch adhesion		100 %
Gloss retention, % (36 months FL)		>92
Delta b (36 months FL)		<0.8

Starting Point Formulation (SPF) – 100% solids on vinyl

Raw Material	Function	Wt. %	Wt. %
ALUA 1	Oligomer, bulk properties	32.7	
ALUA 6	Oligomer, bulk properties		29.4
HDDA	Viscosity control	37.1	40.5
Silica 1	Gloss control	8.0	8.0
Wax 2	Gloss control	4.5	4.5
Wax 3	Gloss control	3.0	3.0
PEA 1	Gloss reduction enhancer	4.0	4.0
Additive 3	Dispersant	4.0	4.0
HALS 1	Weathering	1.2	1.2
UVA 1	Weathering	1.4	1.4
PI 2	Photoinitiator	4.0	4.0
60 gloss – 0 hours QUV		11.7	10.8
60 gloss – 3000 hours QUV		5.4	5.0
Crosshatch adhesion		5B	5B
Color - Delta b (3000 hours)		0.8	1.2

Acknowledgements

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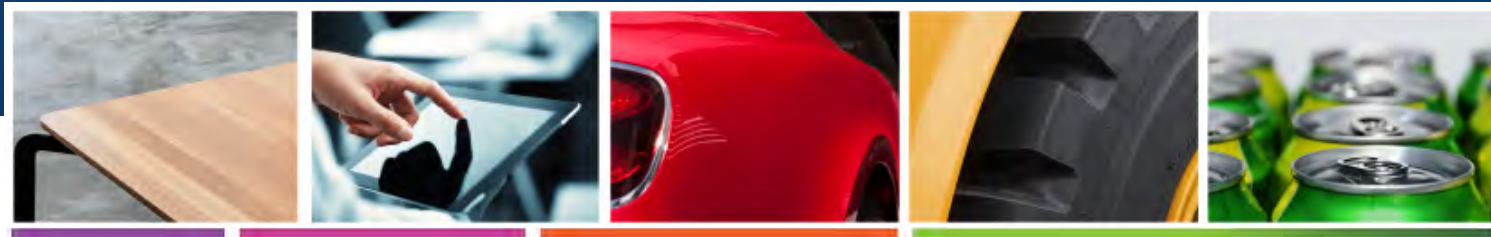
Cedric D'Hulst (Drogenbos, Belgium)

Thank you

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