Electrocoat expanded cure capabilities to resolve EV challenges

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Key Innovation Drivers

Light-weighting

- Multi Substrate enabling Pretreatment
- High throw Ecoat
- Reduced film topcoat systems

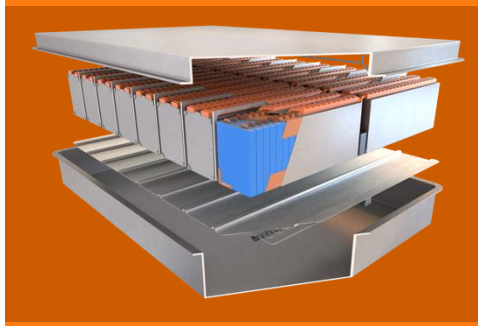
Environmental Emissions

- Water & Waste Reduction Services
- Reduced CO_2 Footprint Products
- Zero Heavy Metal Products
- Low VOC/HAPS Products

Operating & Capital Costs

- Footprint & Facility Design
- Low cure technology
- Process Simplification
- Process Efficiency Services

Electrification



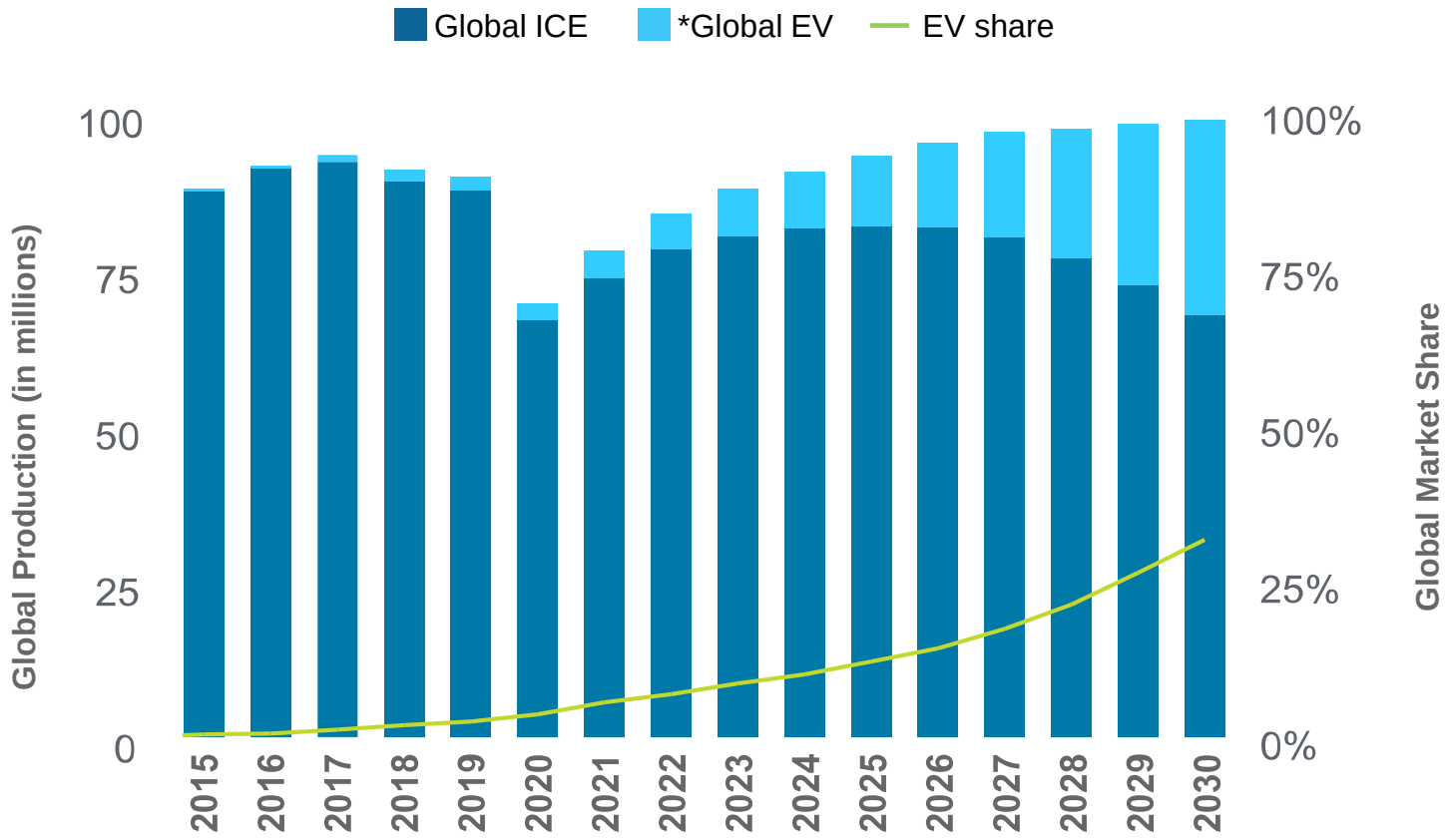
- Battery Cell Coatings
- Adhesives & Sealants
- EMI/RFI shielding
- NVH
- Dielectric Isolation
- Fire Protection

Autonomous & Shared Mobility

- Easy to Clean for Sensors & Lenses
- Radar & Lidar Capable
- Radio frequency interface shielding
- Conductive inks
- Anti-viral interior coatings

Global Light Vehicle Production will Shift to EV

Outlook for Annual Global Vehicle Sales



**Global EV = Combined Global BEV and Global PHEV*

Source: Deloitte analysis, IHS Market, EV-Volumes.com

~7 - 10 million EV's by 2025 and 25 million 2030

Drivers & Geography

Improving Consumer Sentiment

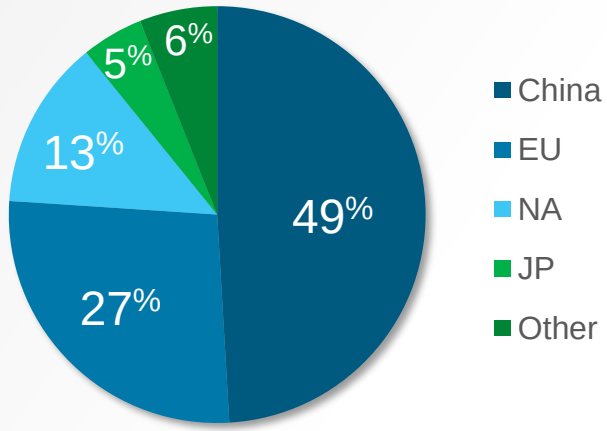
- Better driving range
- Lower cost of ownership
- Improving charging infrastructure
- Enhanced battery safety

Policy & Legislation

- Emissions targets
- City access restrictions
- Financial incentives

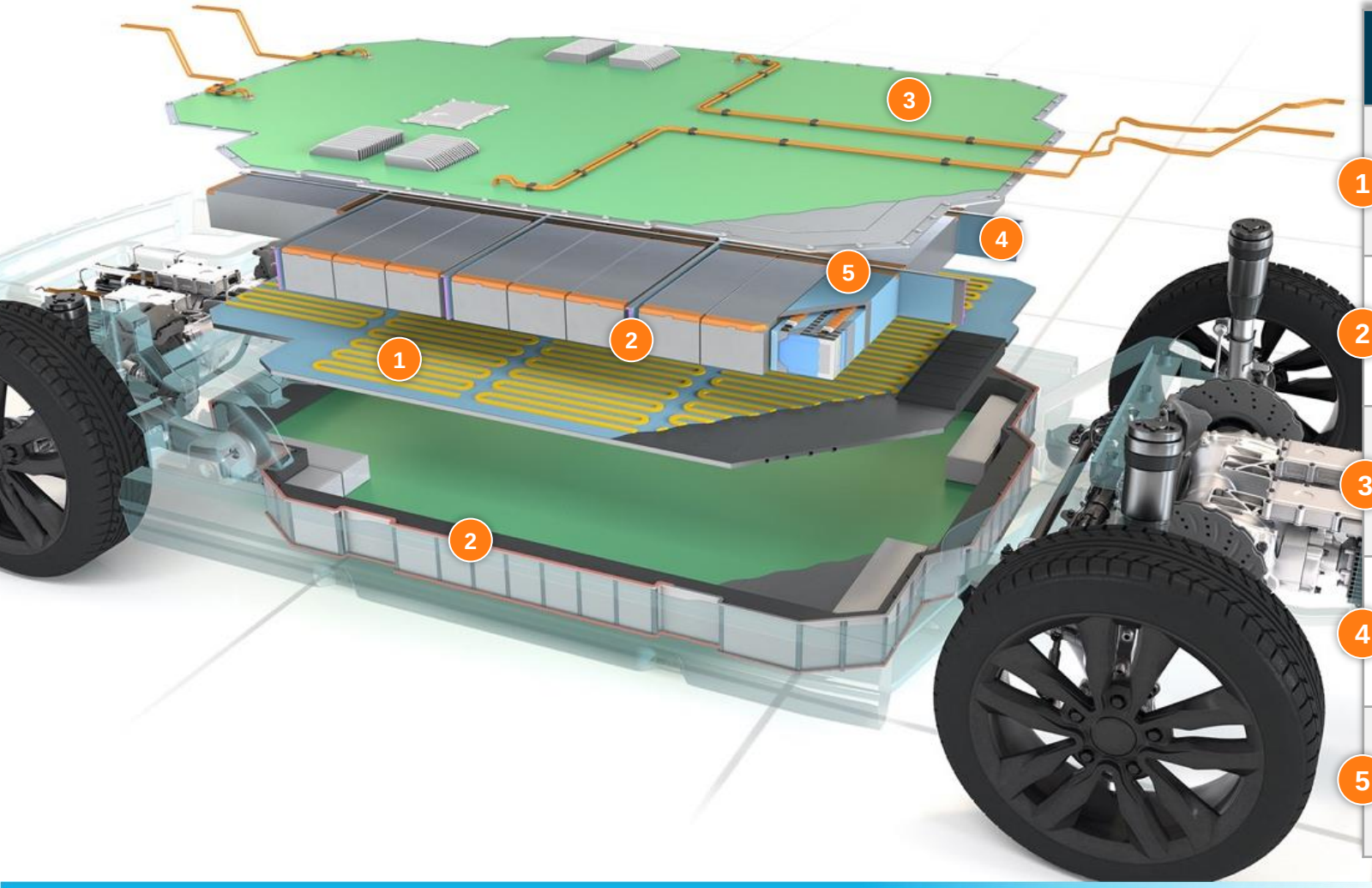
OEM Investments

Regional Mix: Projected 2015 EV Production



Source: IHS Market, EV-Volumes.com

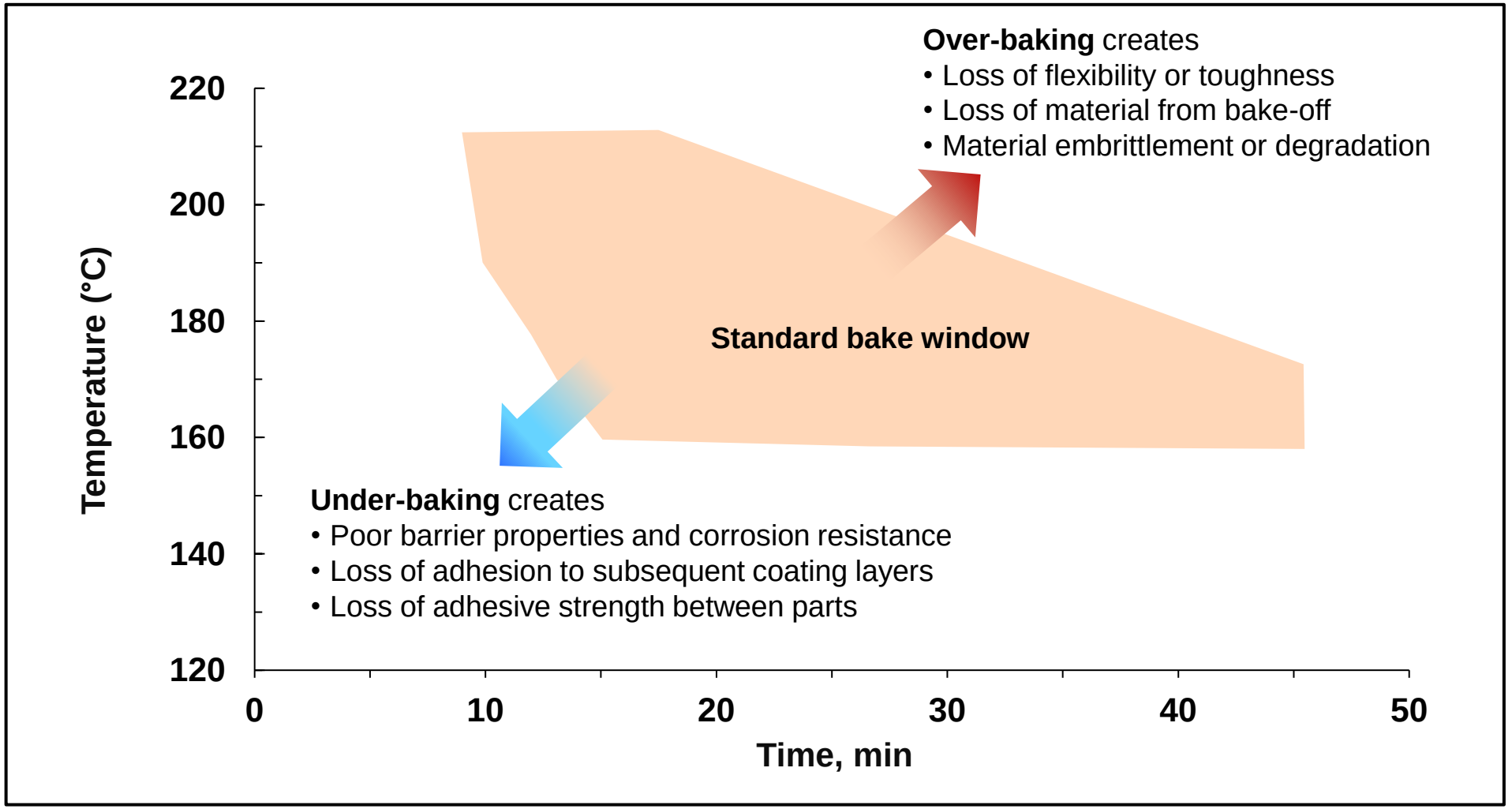
PPG Solutions for EV Battery Packs



TECHNOLOGY	PRODUCTS
1 Thermal Conductive Fillers	• CORATHERM®
2 Adhesives & Sealants	• CORASEAL™ • CORABOND®
3 Corrosion & Impact Protection	• POWERCRON® • ENVIROCRON®
4 Dielectric Protection	• ENVIROCRON® • RAYCRON®
5 Battery Fire Protection	• BFP™

Battery electric vehicles are protected by PPG coatings!

Coating and Adhesive Bake Window

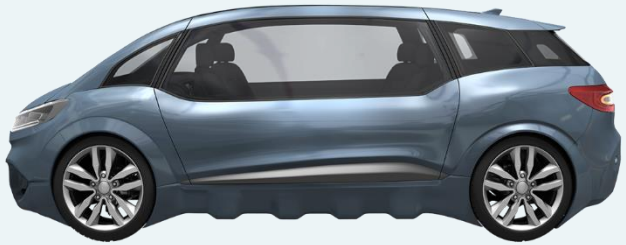


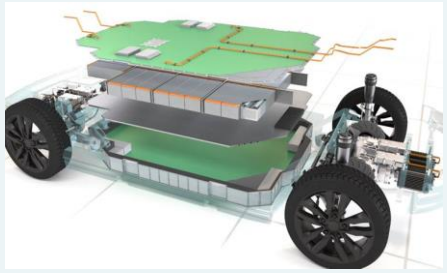
A broad bake window ensures material performance on all parts of a car

Expanded Bake Window Value

Innovative body designs

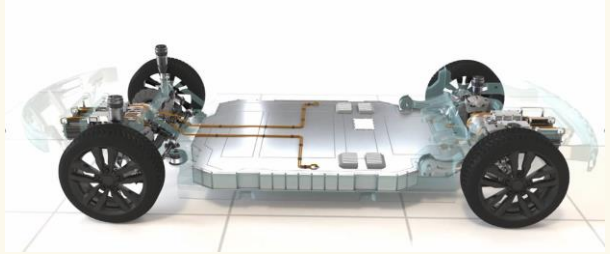
Need for expanded bake window in mobility / electrification





Heavy vehicle construction segments required to protect the battery pack

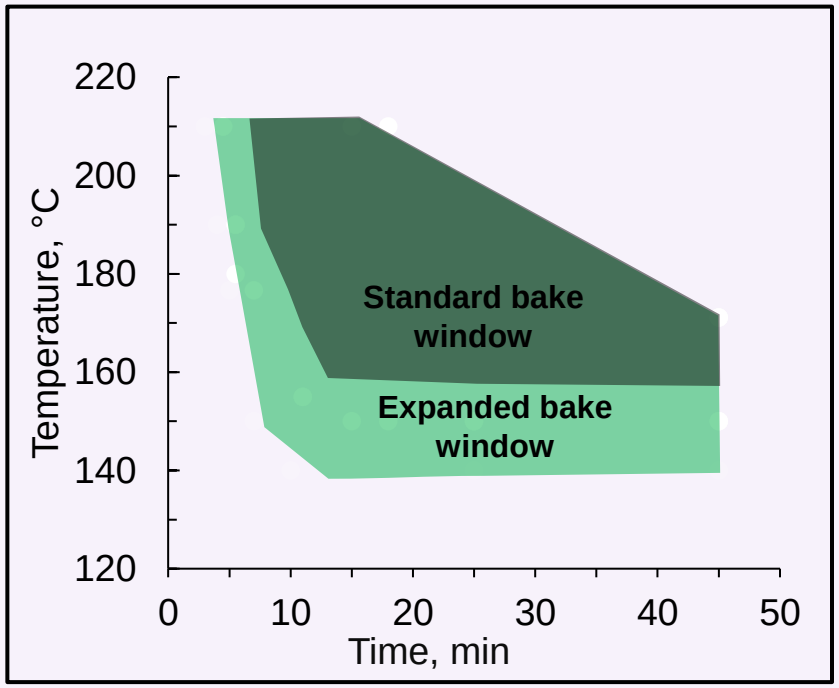
Existing



Heavy segments require more energy to heat up

Current solution: Increase oven temperature or reduce line speed

Expanded Bake Capability



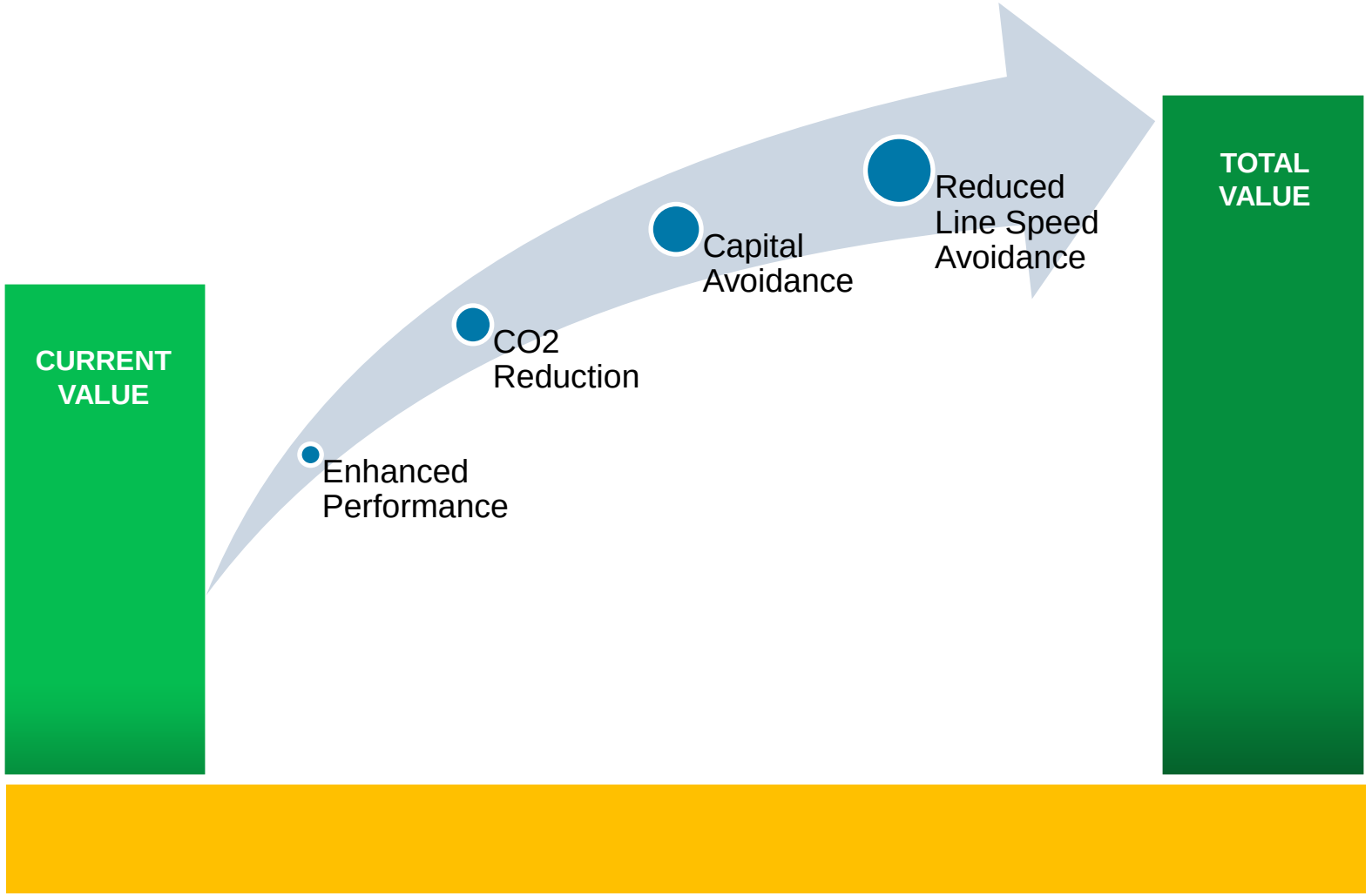
Expanded bake windows enable cure at lower temperatures, shorter times

Expanded bake window materials enable vehicle electrification

Expanded Bake Window Value

Expanded Bake Values include:

- Social responsibility
- Environmental advantages
- Applied cost savings
- Enhanced performance



Growth of Mobility is Creating Multiple Opportunities for the use of PPG Technology

Corabond® Structural Adhesives:

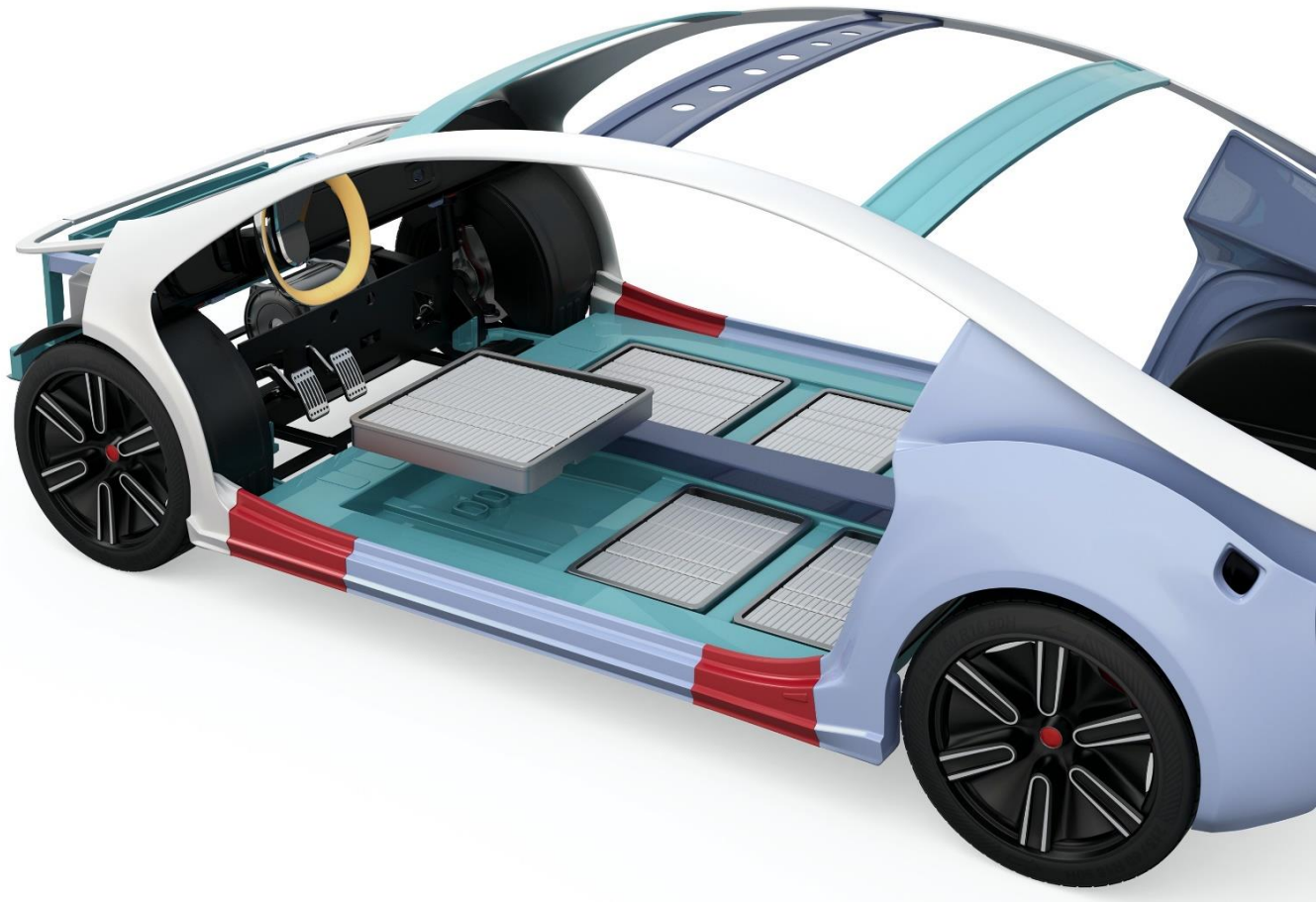
Designs driving lower cure requirements for structural adhesives:

- Thicker metal components = slower and variable bondline heating

Enviro-Prime®:

Designs driving lower cure requirements for electrocoat :

- Expanded bake electrocoat = lower oven temperatures

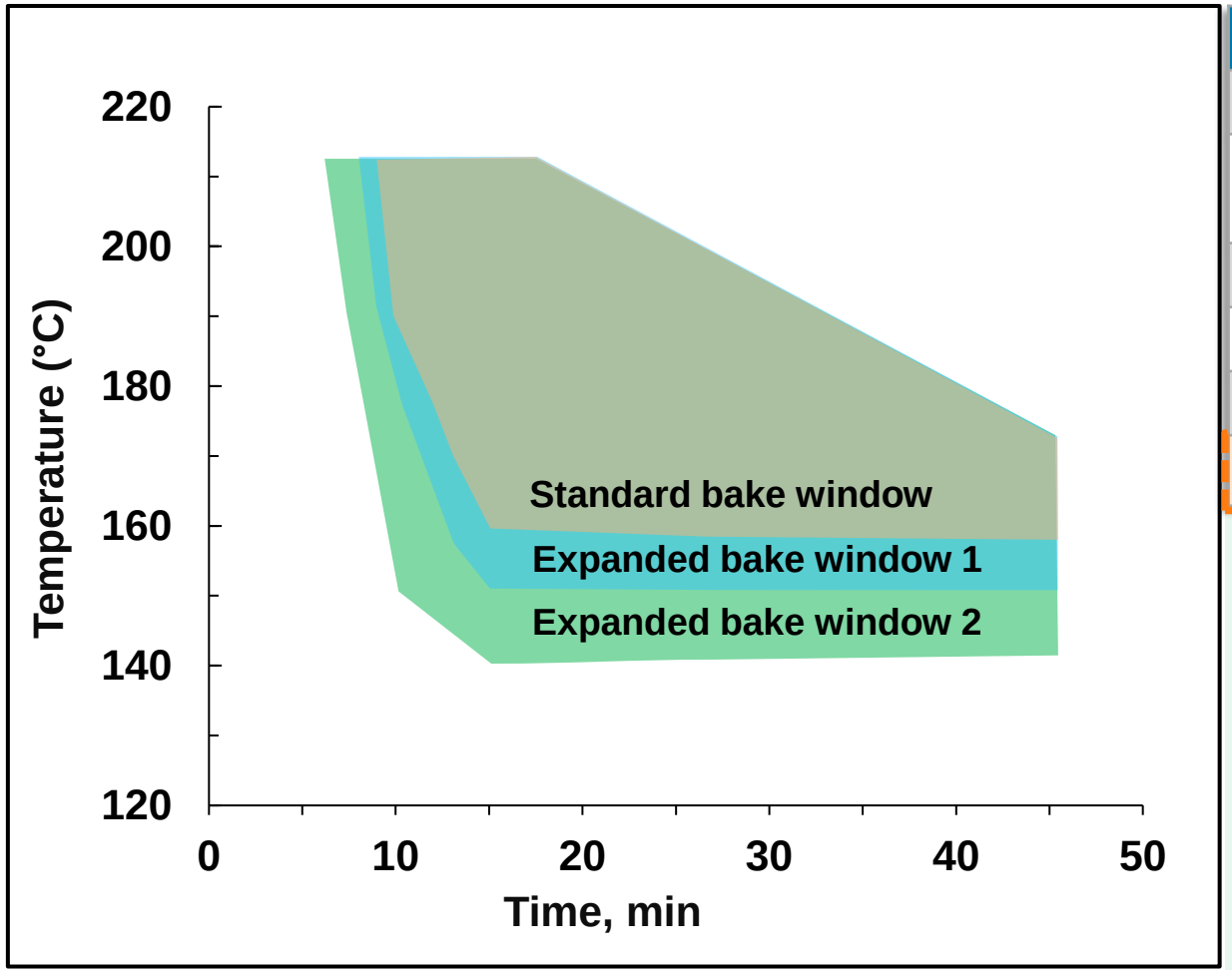


Enviro-Prime® Epic

Electrocoating (or E-coating) is:

- A method for applying a coating using electric current to deposit material onto a conductive substrate.
- Capable of protecting all surfaces of complex assemblies.
- A highly efficient and automated process.
- *Required for corrosion protection*

Expanded Bake Enviro-Prime® Epic



Attribute	Enviro-Prime® Epic 300
Reduced biocides	✓
Reduced sanding (bullseye, run outs, crater control)	++
Reduced water usage	✓
Reduced cleaning (carrier and UF)	✓
Reduced oven filter change	✓
Expanded bake window 150 °C/140 °C	✓

Expanded bake 140 °C cure enables vehicle electrification

- ✓ **No CapEx for ovens**
- ✓ **No reduction in line speed**

Enviro-Prime® Epic 300 will reduce applied cost and enable vehicle electrification

Expanded Bake Ecoat – Formulation Optimization

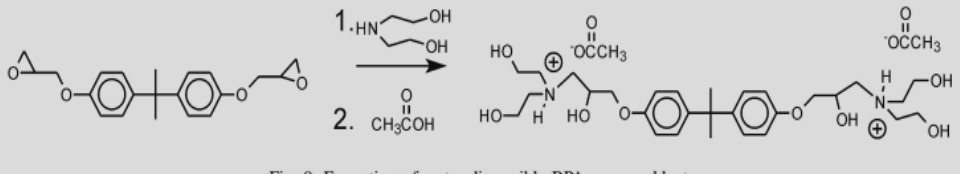


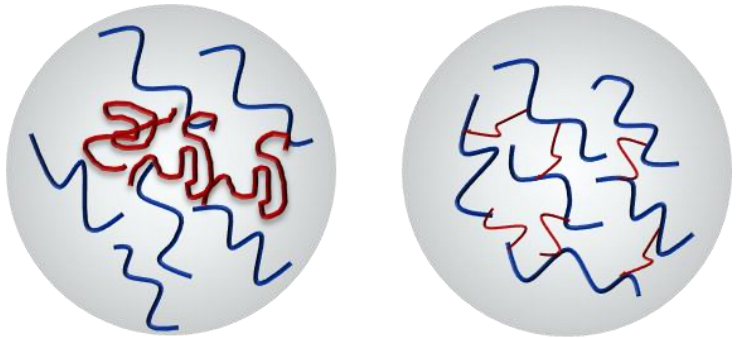
Fig. 9. Formation of water-dispersible BPA epoxy adduct.

D. A. Wicks, Z. W. Wicks Jr., Prog. Org. Coat. 41 (2001) 1-83

Cross-linking chemistry

Cationic electrocoat paint with complete cure in a wide range of processing temperatures/time

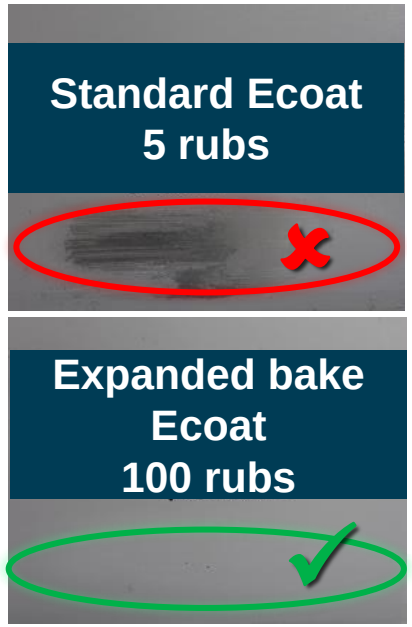
Cationic Electrocoat Resin



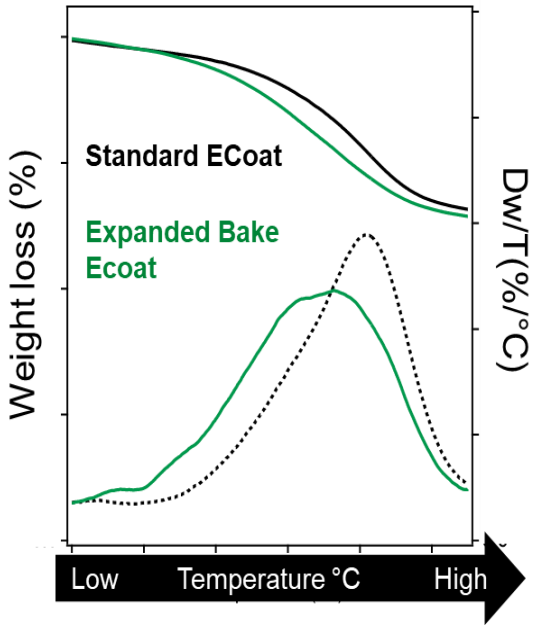
→ **Polymer**

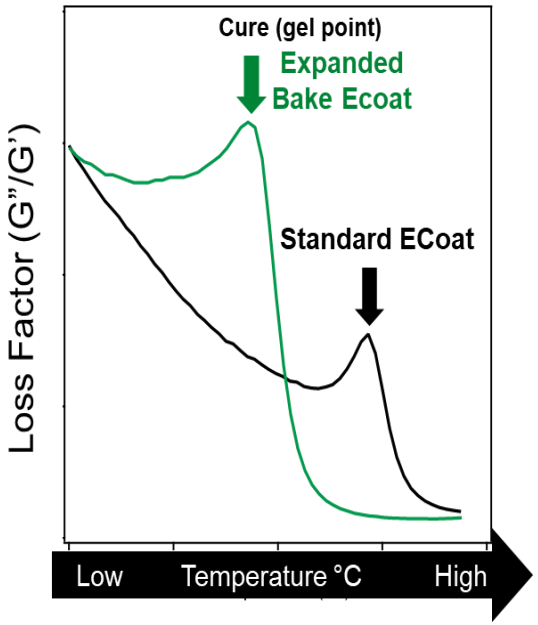
→ **Cross-linker**

Solvent Rub Test



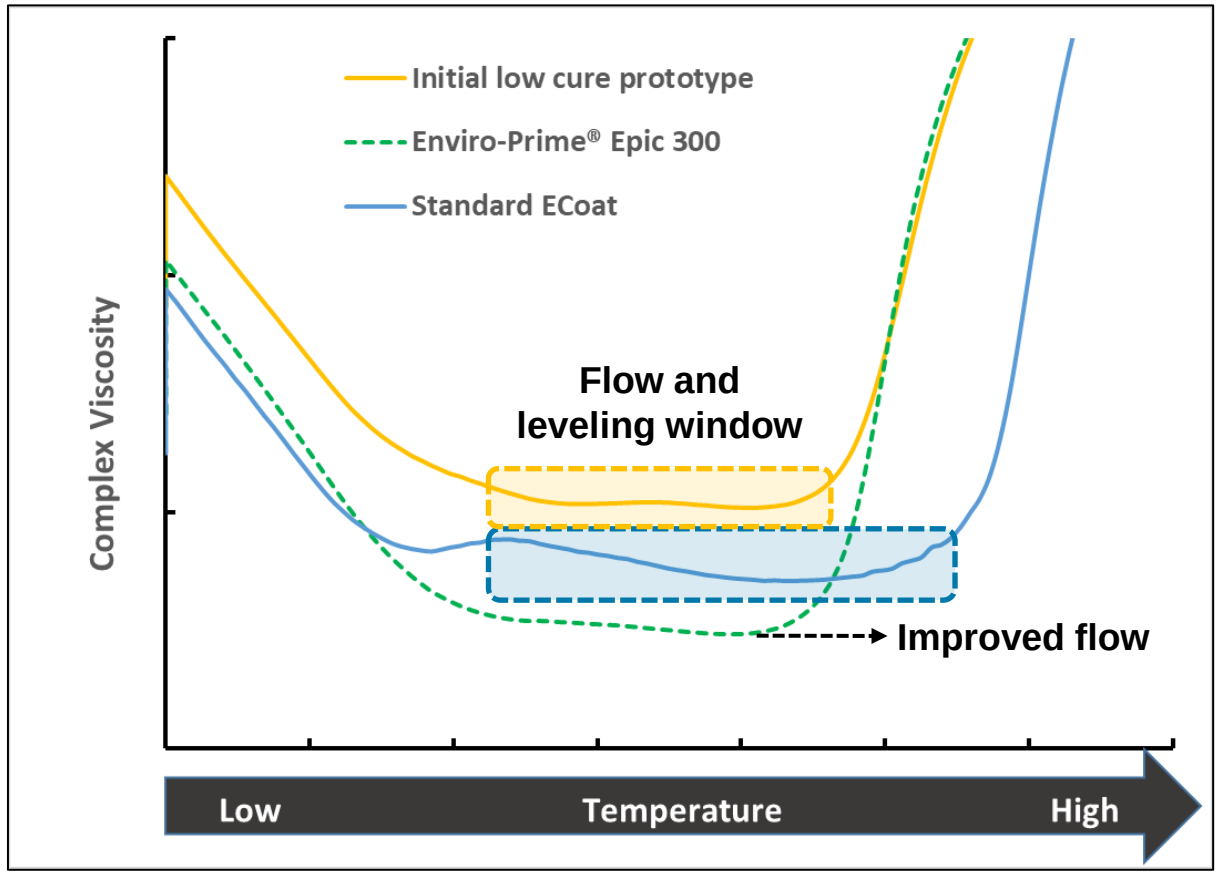
Thermogravimetric Analysis & Rheology





Resin chemistry and formulation optimized to achieve target properties @ 140 °C cure

Expanded Bake Ecoat – Appearance Optimization



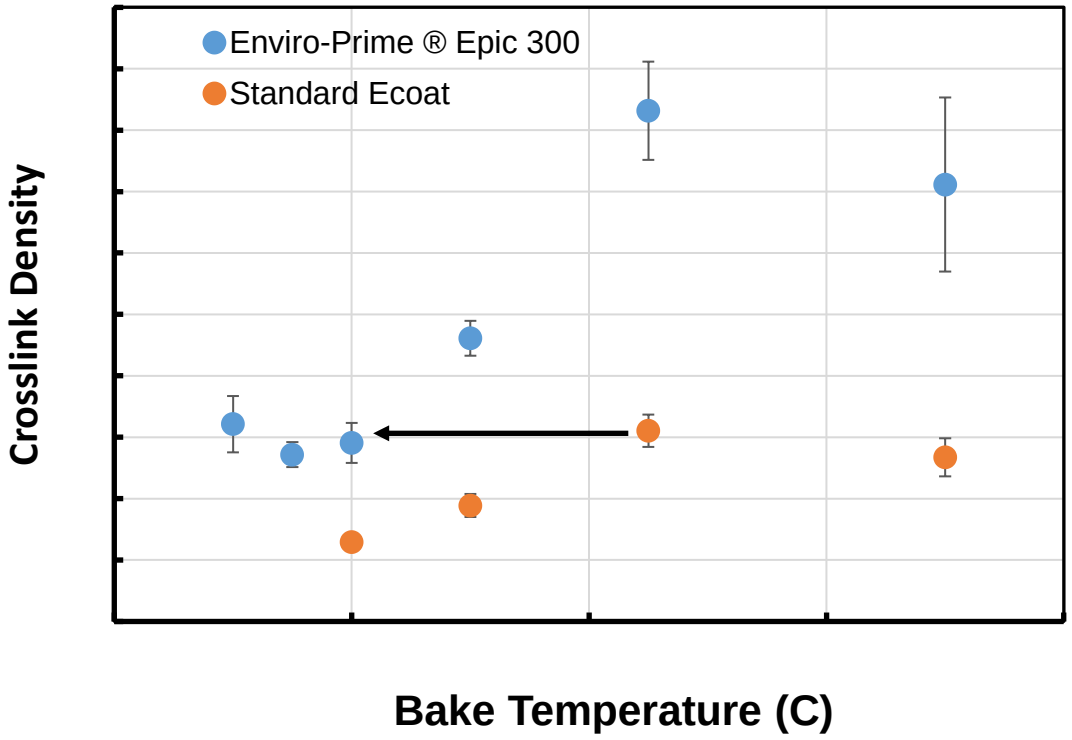
Rapid cure onset for expanded bake prototype narrows flow and leveling window, increasing E-coat roughness

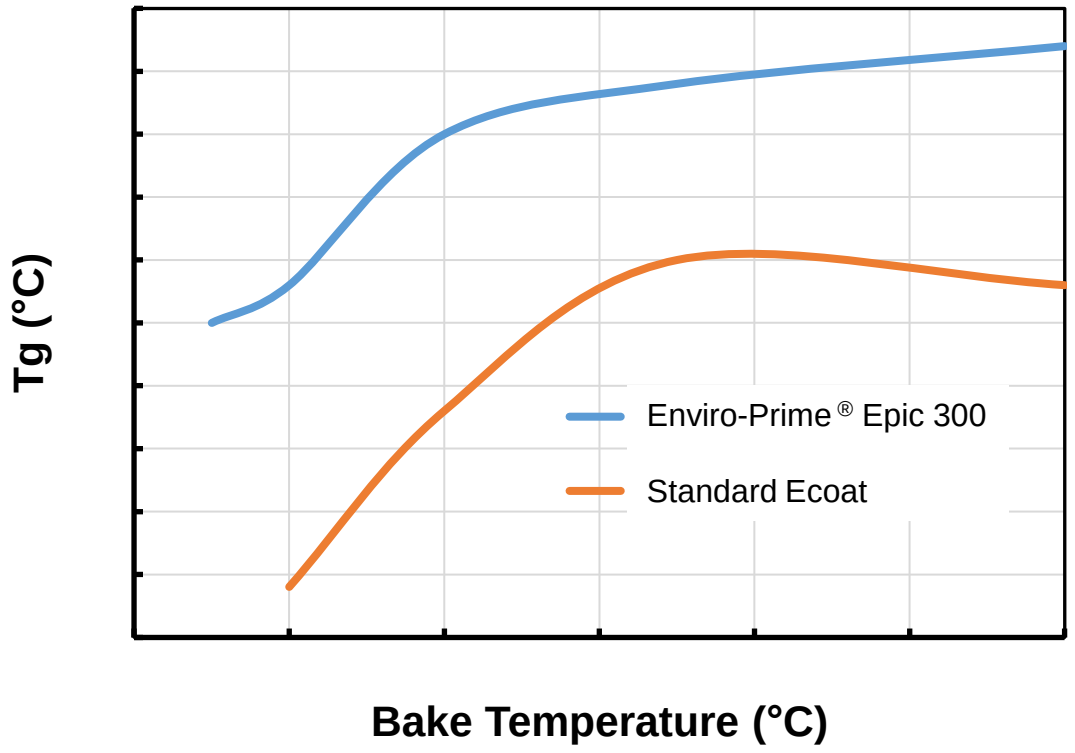
Resin type	Appearance	140 °C cure
Standard Ecoat		
Initial low cure prototype		
Enviro-Prime® Epic 300		

Resin modified for improved flow and leveling meets smoothness target while maintaining low temperature cure

Cure/appearance balance achieved via polymer resin optimization

Expanded Bake Ecoat – Cure Properties



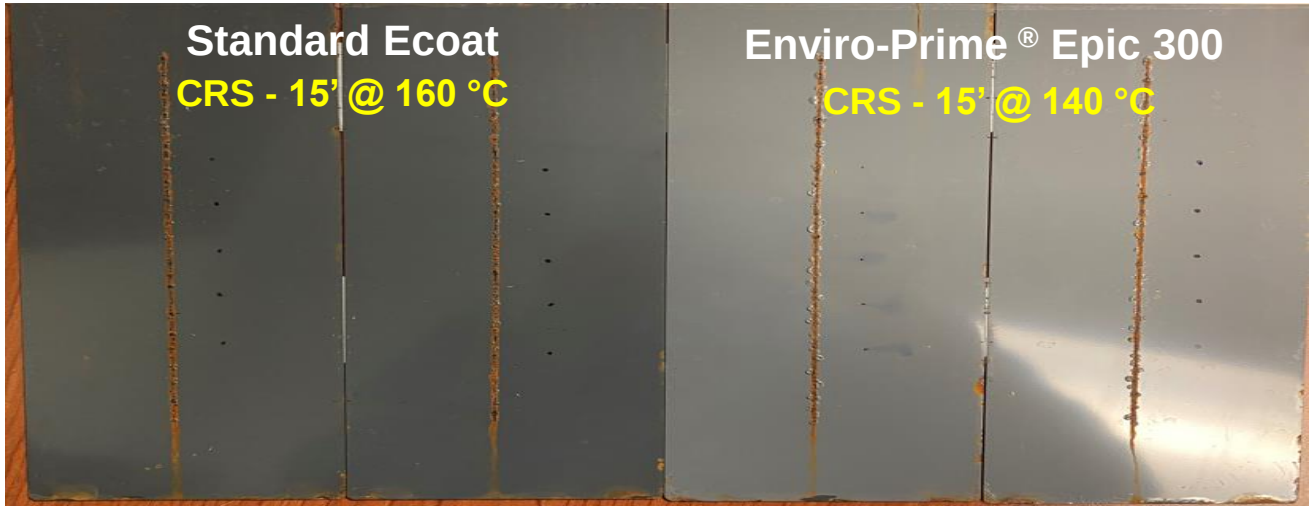


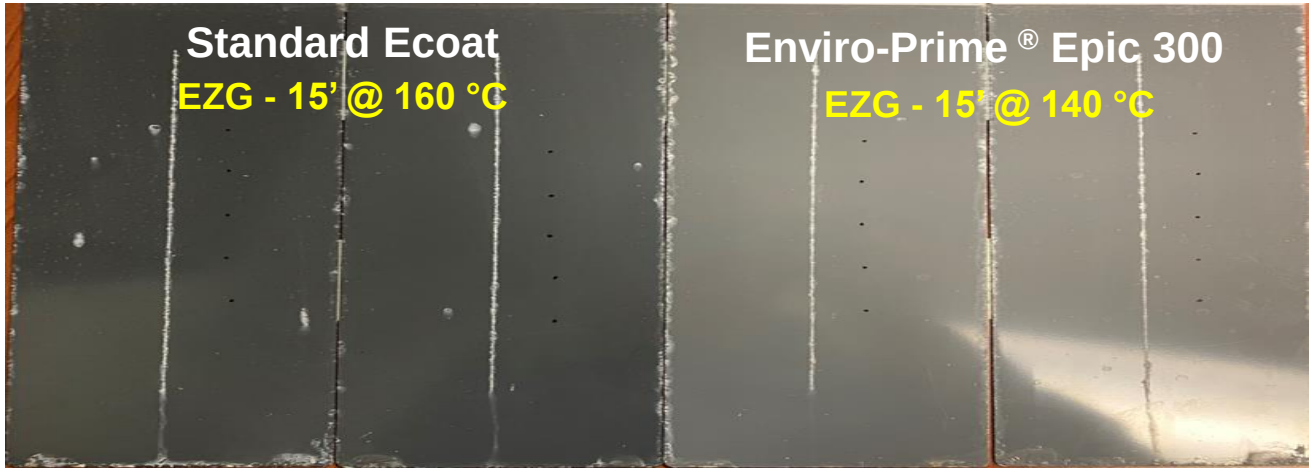
Able to achieve same cross link density at lower temperatures.

Increased crosslink density at lower temperature gives higher Tg → better barrier properties

Increased cross link density and Tg at lower bake temperatures for improved corrosion resistance

Enviro-Prime® Epic 300 Performance





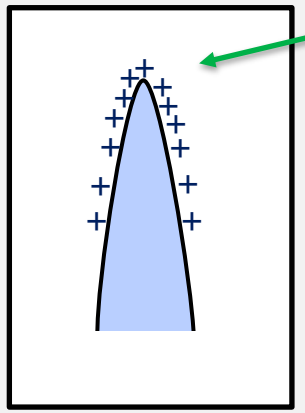
Property	Standard Ecoat	Enviro-Prime® Epic 300
Appearance	✓	✓
Expanded bake window Cure: 150 C		✓
Expanded bake window Cure: 140 C		✓
Corrosion	✓	✓

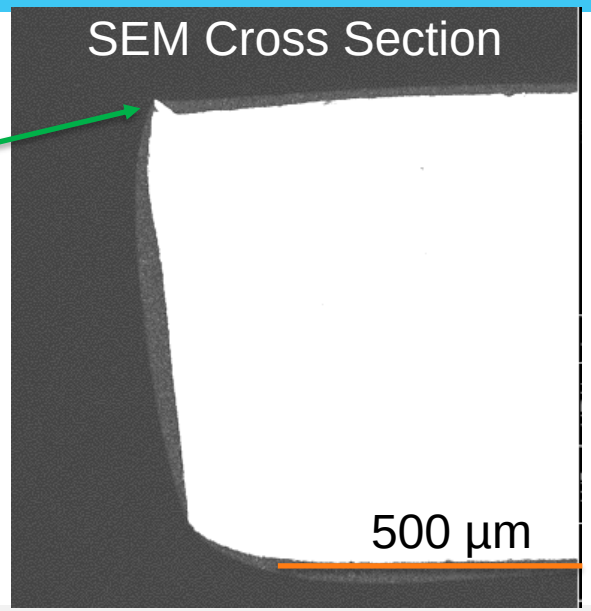
Enviro-Prime Epic 300 meets corrosion performance even @ 140 °C bake

Electrodeposition on an Edge

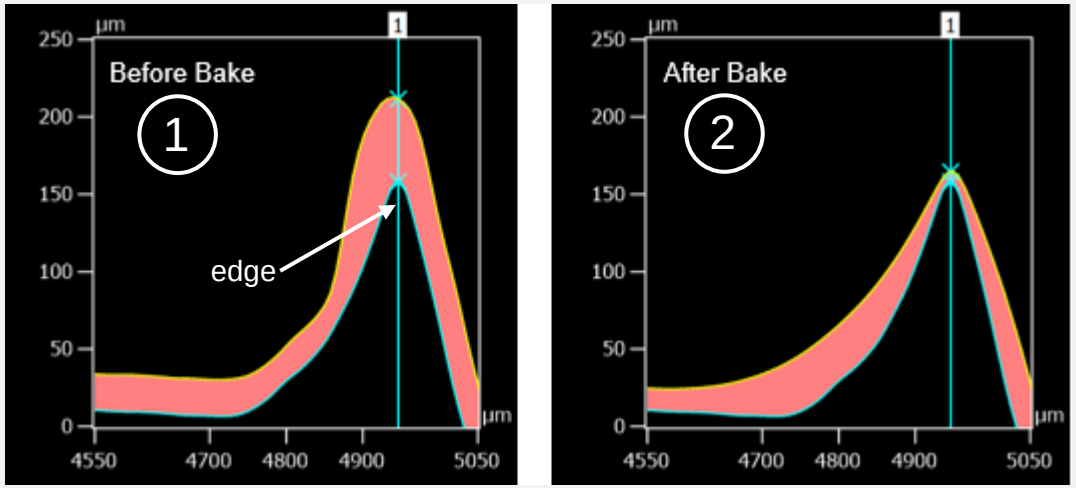
Charge Accumulation on Edges

Charges accumulate at sharp points, which results in stronger electric field close to the edge





Consequences for Electrodeposition



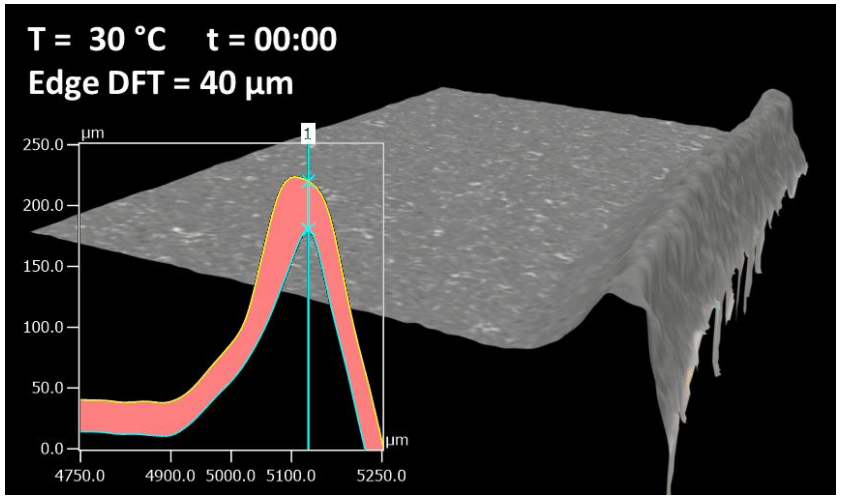
eCoat layer

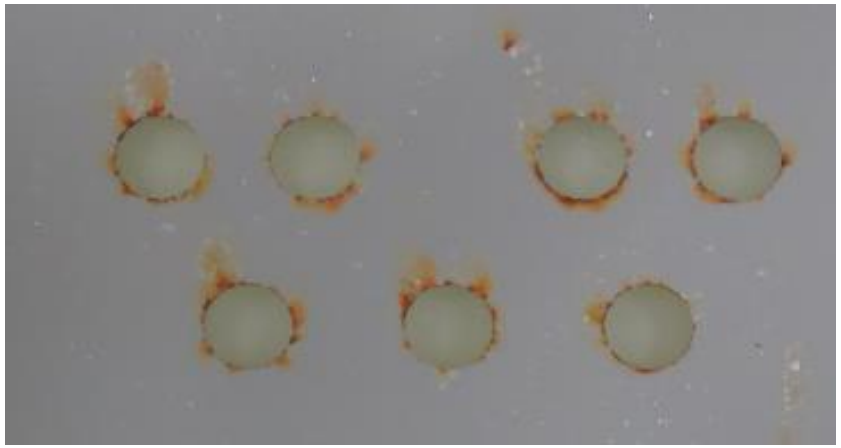
1. Because of the antenna effect, thicker films are initially deposited at the edges
2. After bake, the film flows away from the edge because of surface tension forces and film shrinkage

Edge protection in Ecoat is primarily a flow problem.

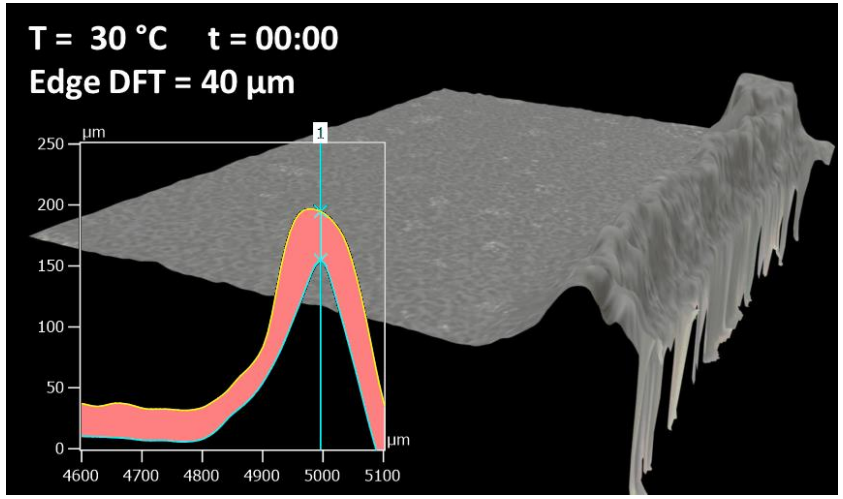
Edge Coverage – Electrodeposition and Bake Process

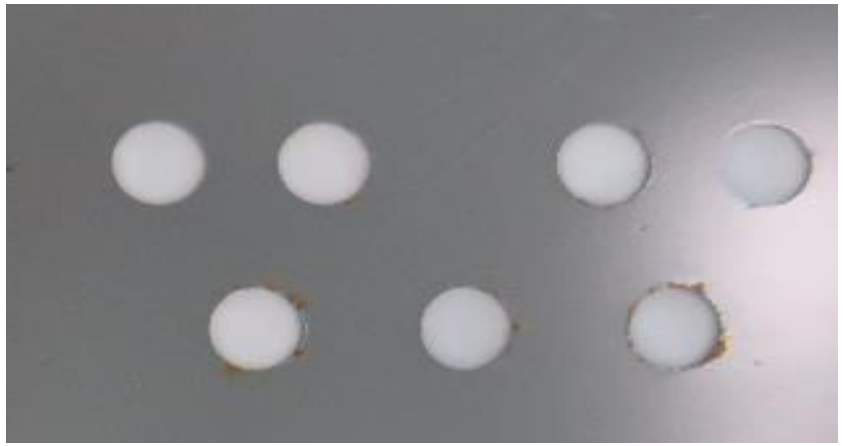
Standard Ecoat





High Edge Ecoat



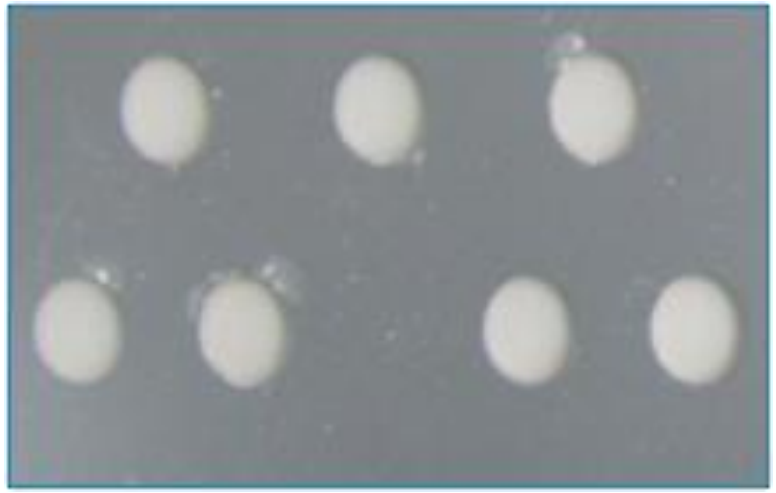


Stages During Bake

	Stage	Start (°C)	End (°C)
1	Degassing	30	120
2	Flow	90	140
3	Shrinkage	120	220
4	Cure	150	220

Flow and film shrinkage due to weight loss lead to poor edge coverage and corrosion resistance.

Expanded Bake Ecoat – Edge Corrosion Capable

	EZG - Phosphate Pretreatment	EZG - Thin Film
165 °C		
150 °C		

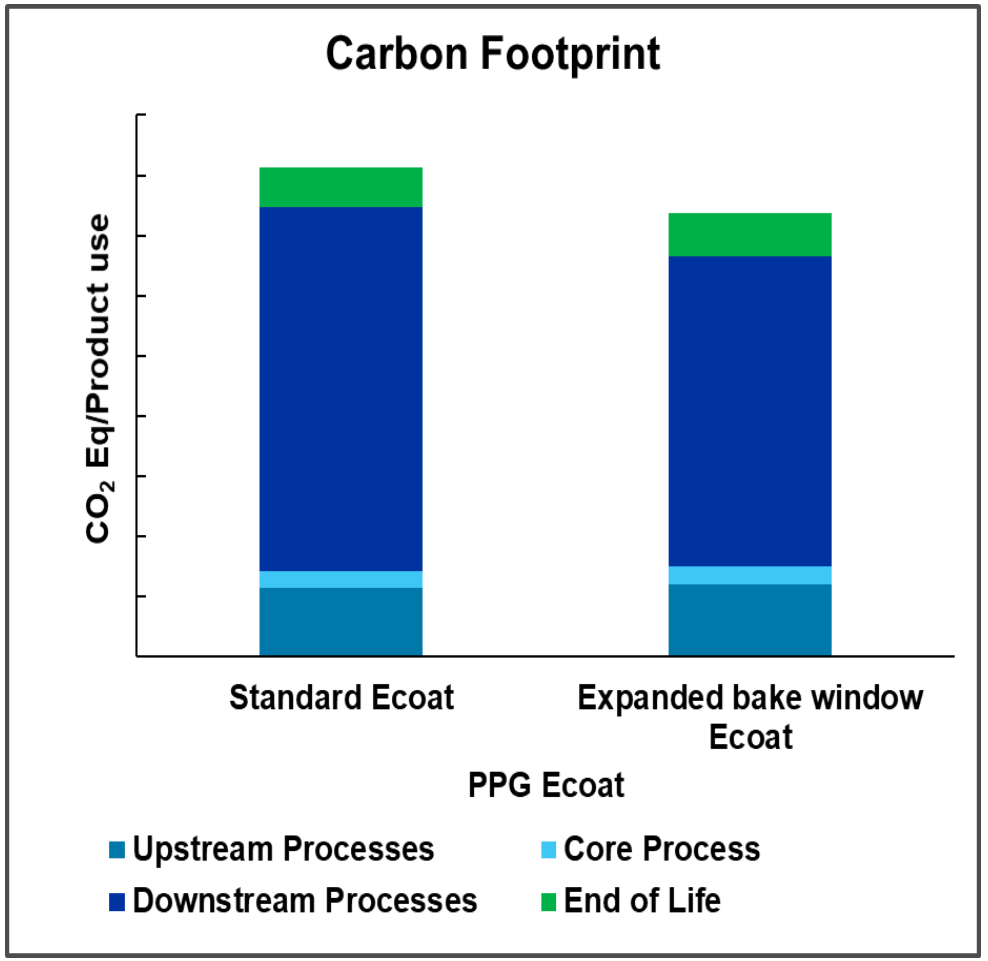
Edge corrosion prevention is possible with optimized formulations

Life Cycle Analysis





Process					
Upstream	U1 Raw material supply	U2 Transport raw material	U3 Packaging supply	U4 Packaging transport	-
Downstream	D1 Transport to paint shop	D2 Disposal of packaging	D3 Product VOC emissions	D4 Losses during application	D5 Customer application process
Core	Core PPG processes				
End of life	Disposal at end of life				



Lowering oven temperature can potentially reduce CO_2 emissions

Corabond® & Enviro-Prime® Epic 300 Expanded Bake Technology

ENVIRONMENTAL / REGULATORY

- Enables EV vehicle design (battery pack protection)
- Reduce carbon footprint
- Enables light weighting
- Reduce water consumption
- Non tin catalyzed **

PROTECTION / ENHANCEMENT

- Excellent adhesion to multiple substrates*
- Enables static and dynamic performance improvements*
- Corrosion protection
- Expanded lower end cure window

EASE OF USE / ROBUSTNESS

- Robotically applied*
- Reduction of weld applications*
- Body and closure application applicability*
- Compatible with zirconium pretreatment and compressed process decorative coatings**
- Reduced biocide consumption**

COST REDUCTION

- Reduced need for investment in redesign of existing paint line
- No capital investment from the customer
- Reduced natural gas
- Utilize existing e-coat settings and use
- Lower water consumption **

** Corabond*
*** Enviro-Prime® Epic 300*

Questions ???

Thank You for joining us, we look forward to answering any questions you may have.

We protect and beautify the world™