High-Solids TEA-Free Waterborne Polyurethane Dispersions

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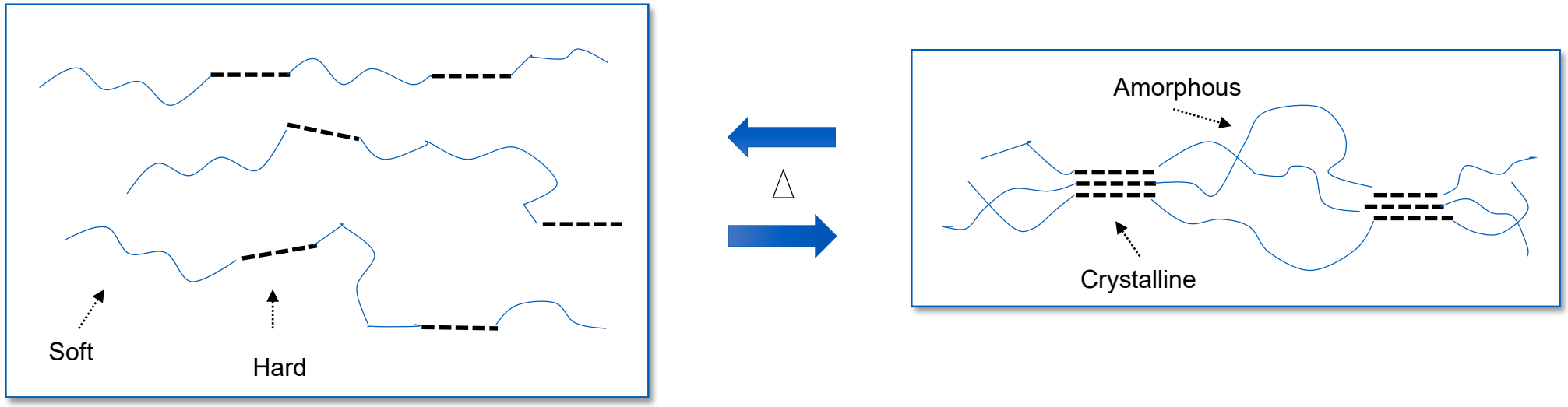
Agenda

- Introduction
- Sustainability Targets
- Benefits of High Solids
- Introduction to High Solids Polyurethane Dispersions
  - HSPUD1
  - HSPUD2
  - HSPUD3
- Conclusions

Introduction: What is a Polyurethane?

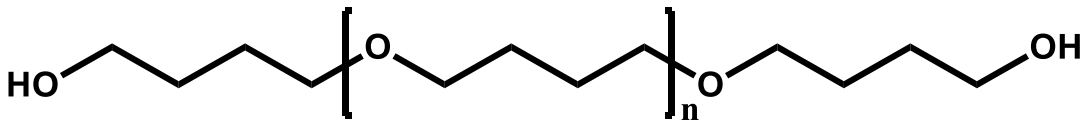
- Polymer made from segments of amorphous (soft) blocks and crystalline (hard) blocks
- Tend to have better toughness and resistance properties compared to polyacrylates
- Performance is strongly influenced by **soft segment**
- Polyurethane polymer chains can be modified to be dispersible in water – forming polyurethane dispersions



Polyurethane Soft Segments

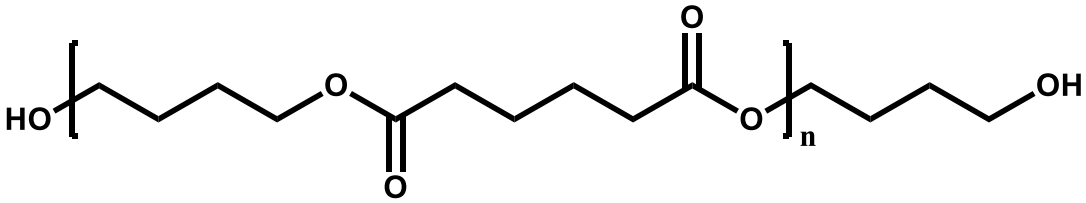
Polyether polyol

Good hydrolytic stability,
Poor UV resistance



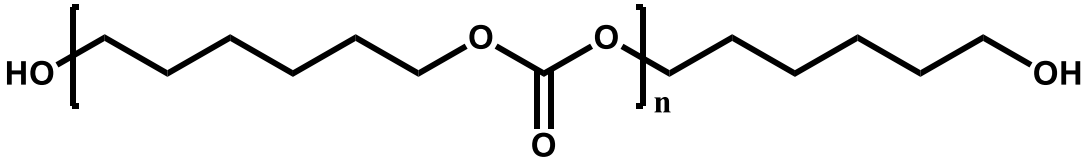
Polyester polyol

Good mechanical properties and
UV resistance, Poor hydrolytic stability



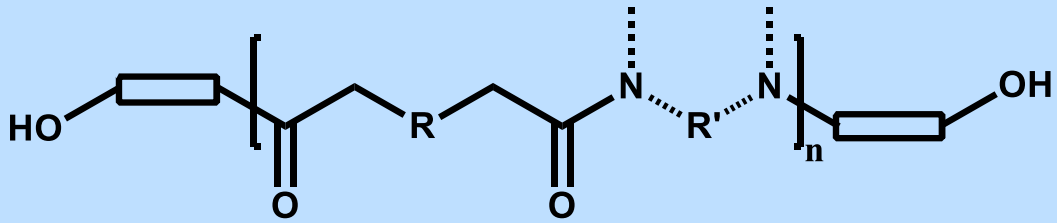
Polycarbonate polyol

Good UV and hydrolytic stability, high
price and limited composition variability



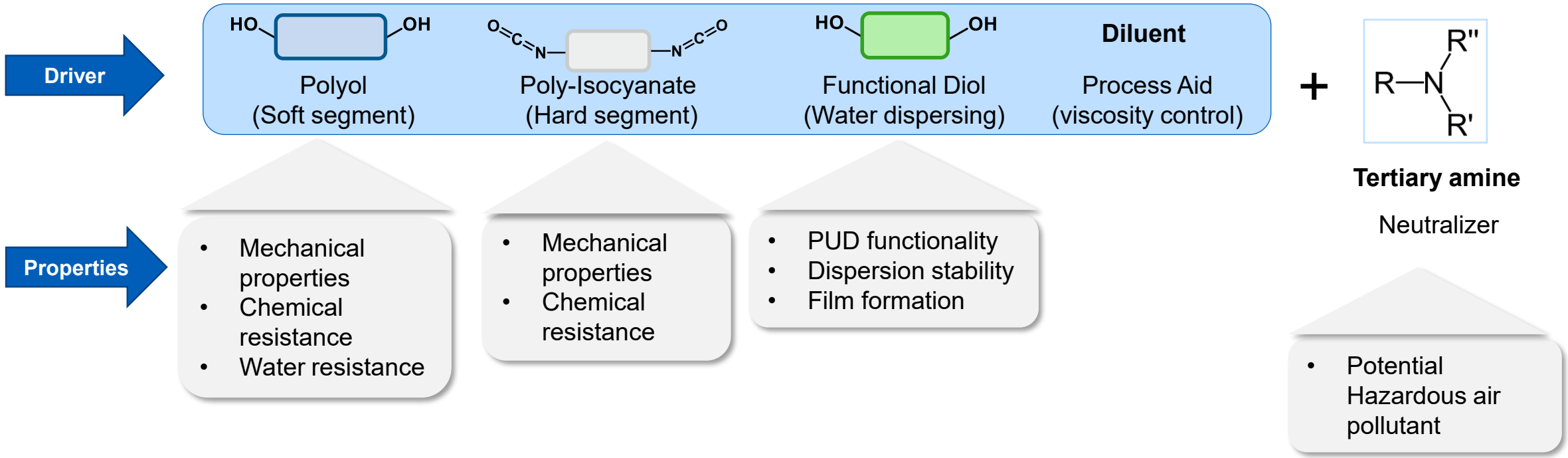
Polyamide polyol

Excellent mechanical properties
Hydrolytic stability >> Polyester
UV resistance >> Polyether
Composition flexibility >> Polycarbonate



Typical Polyurethane Dispersion (PUD)

Multiple **compositional drivers** which affect critical **performance properties**.



- Solids content of PUDs are typically limited by polymer design choices
- Polymer and particle morphology can be constrained when synthesizing high hardness PUDs

High Solids PUDs – Framing the Problem

- High solids PUDs currently available
  - Very soft or elastomeric
  - Textile and other flexible substrate applications
  - Low MW polyols – 2K system with isocyanates (hazardous)
- Challenges facing high solids PUDs for rigid substrates
  - Viscosity
  - Dispersion and formulation stability
  - Mechanical properties
- Our goal
  - High solids (45-50%)
  - Low Viscosity (<500cP)
  - High stability
  - **High performance**

Sustainability and Innovation Drivers

Sustainability

- Enable high quality indoor air
- FREE of materials of concern
- Bio Carbon Renewable Content
- Reduce CO_2 emissions

Performance

- Extended durability
- Chemical resistance
- Mechanical properties

Productivity

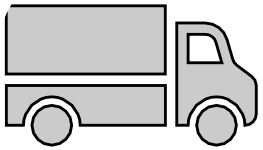
- Simplifying the paint process
- Reducing the total applied cost
- Faster return to service

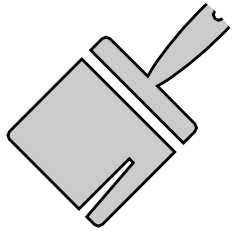
Innovation Targets
High End Wood Coatings

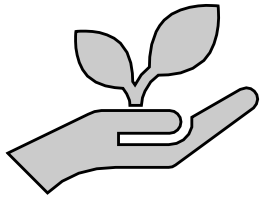
Minimizing our Footprint

Maximizing our Handprint

Benefits of High Solids – Adding Value







Manufacturers

Ship +35% more resin

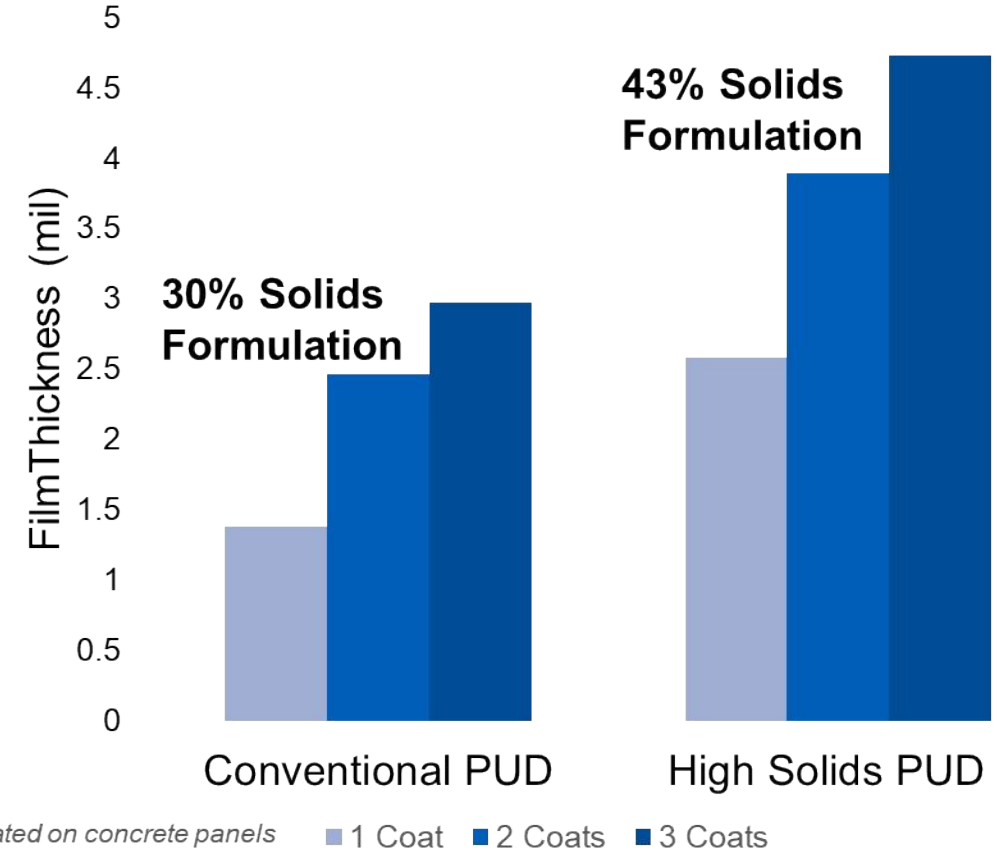
Painters

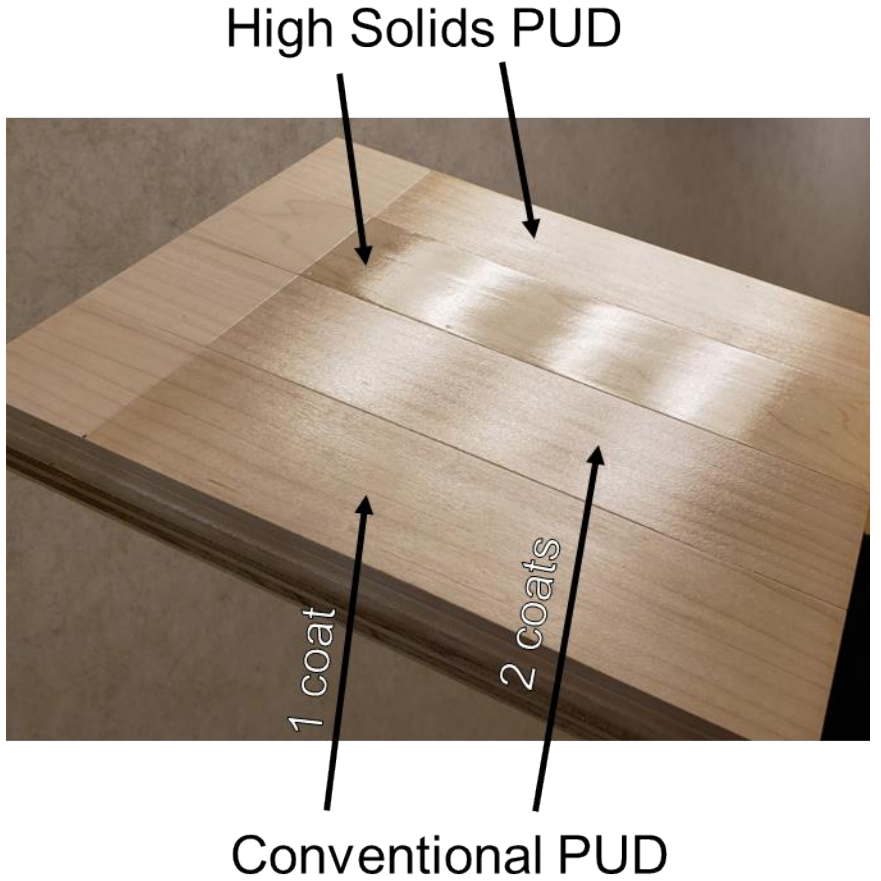
+50% more productive

Everyone

Reduce CO_2 up to 30%

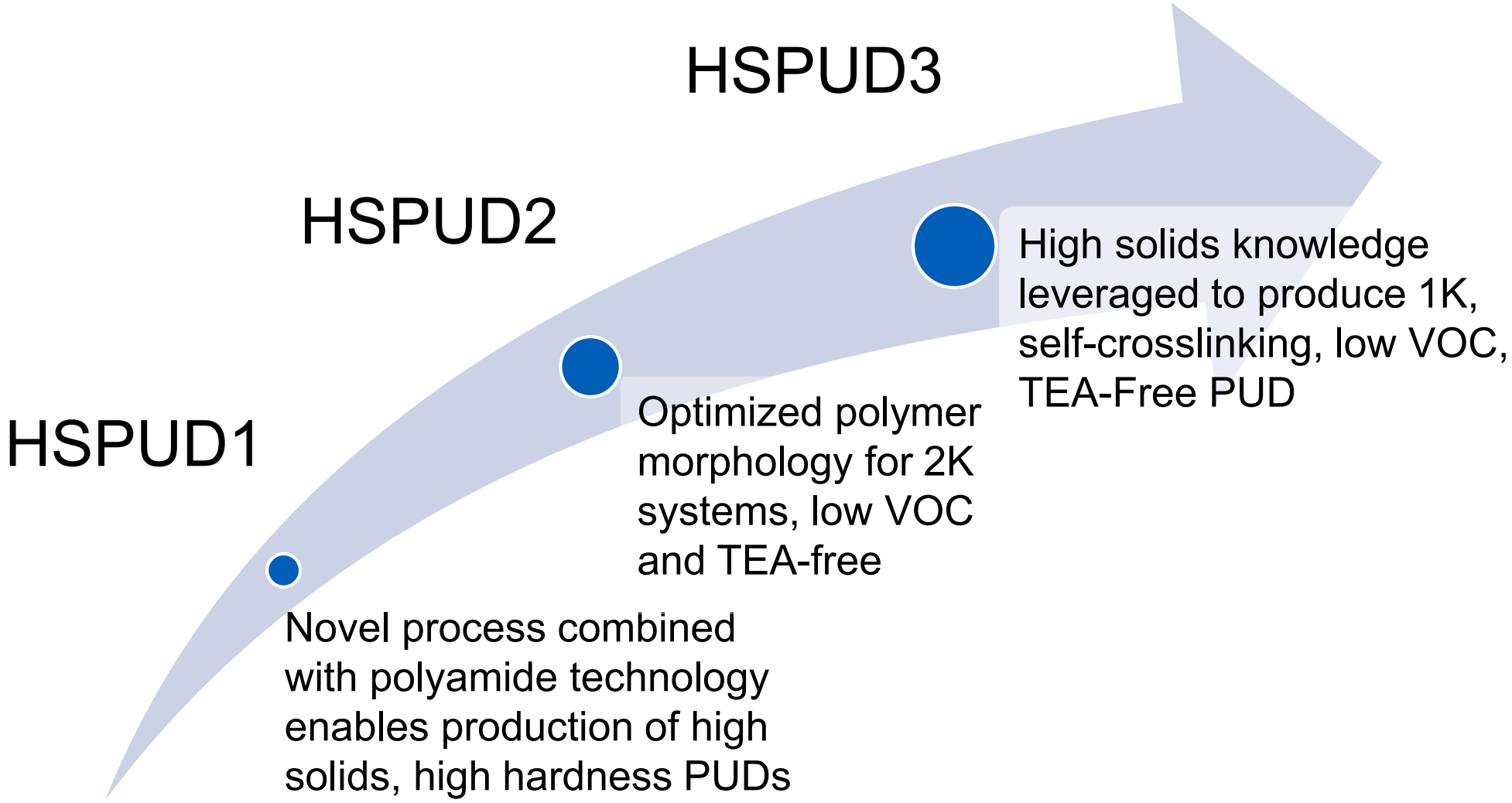
Benefits of High Solids – Film Build and Clarity





Higher film build while maintaining clarity with fewer coats = Faster return to service

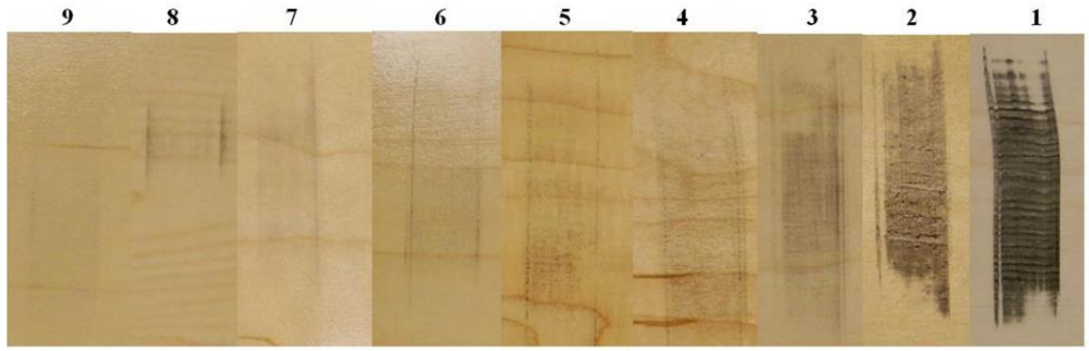
Timeline – High Solids PUD Development

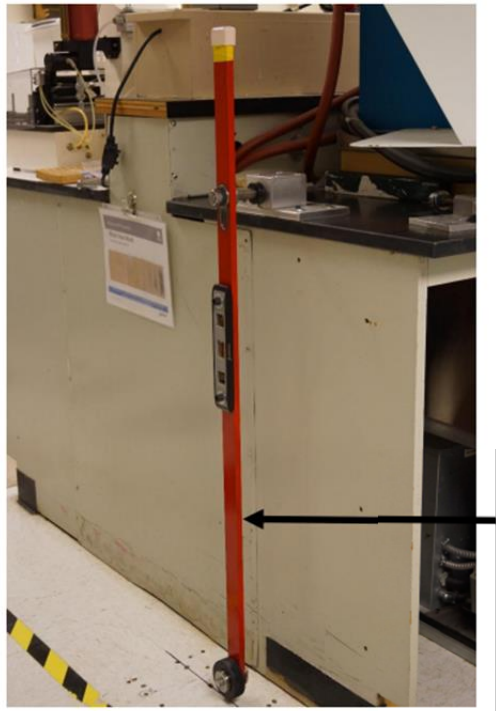


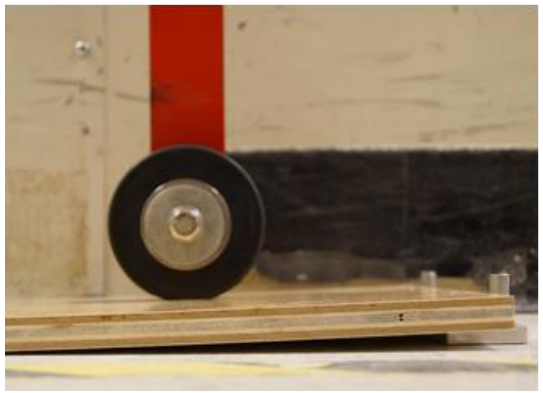
Test Methods

- **Gloss**
  - ASTM D523
- **Black heel mark**
  - Lab developed method
  - Vulcanized rubber puck strikes board at incline
  - Qualitative rating after wiping board with water and cloth
- **König hardness**
  - ASTM D4366, coated on aluminum, 1 week cure
- **Taber abrasion**
  - ASTM D4060, CS-17 wheels,1000 cycles
- **Chemical resistance**
  - German DIN 68861-1:2011-01,16h exposure (category 1A)
  - Exposure time was shorter for chemicals that completely failed before 16 hours (category 1B or 1C)

Black Heel Mark Score (10 best)







Scuff Tester Arm
Bench Height 36inch

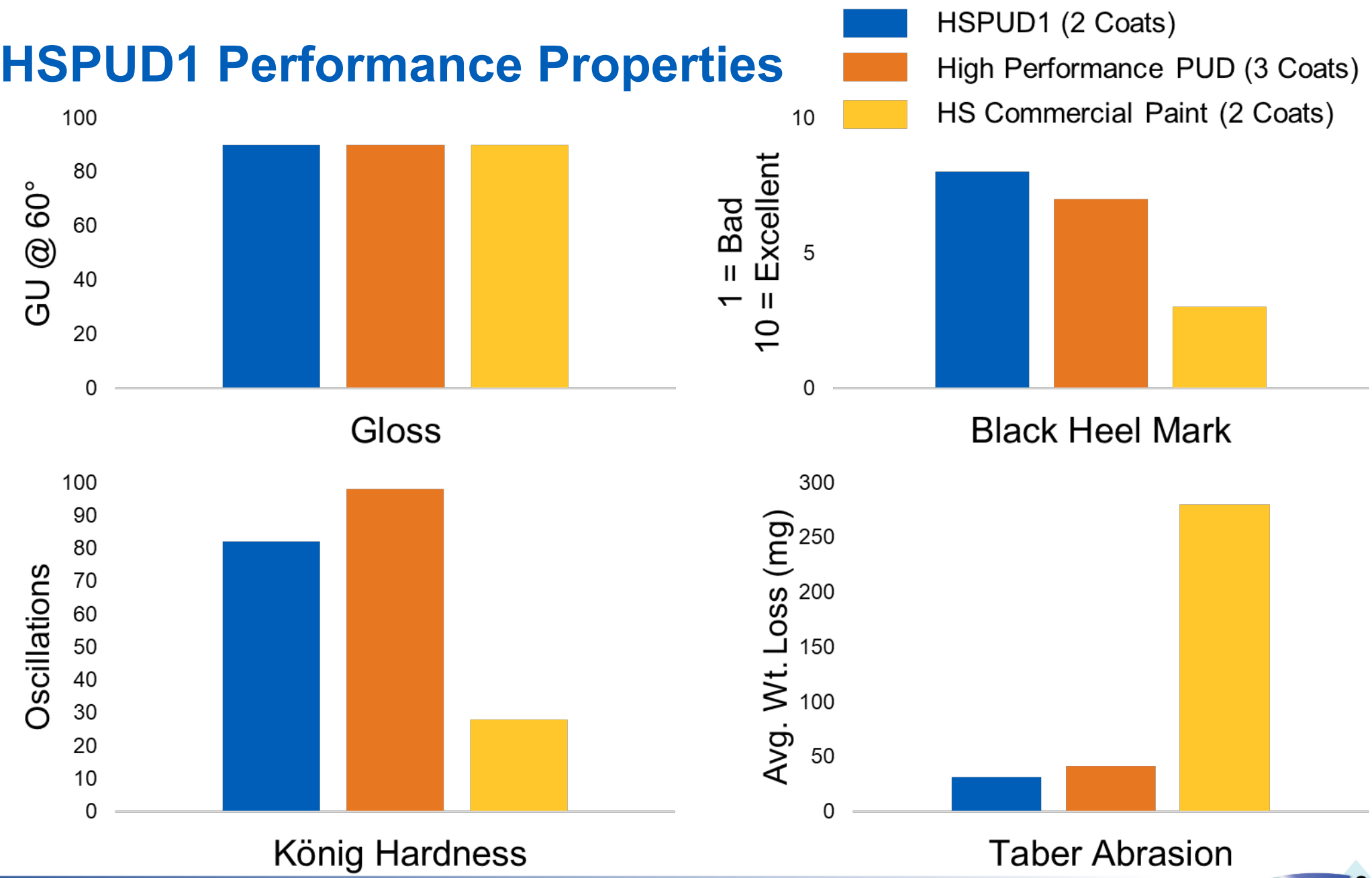
1st Generation High Solids PUD – HSPUD1

High Solids Polyamide Based Polyurethane Dispersion

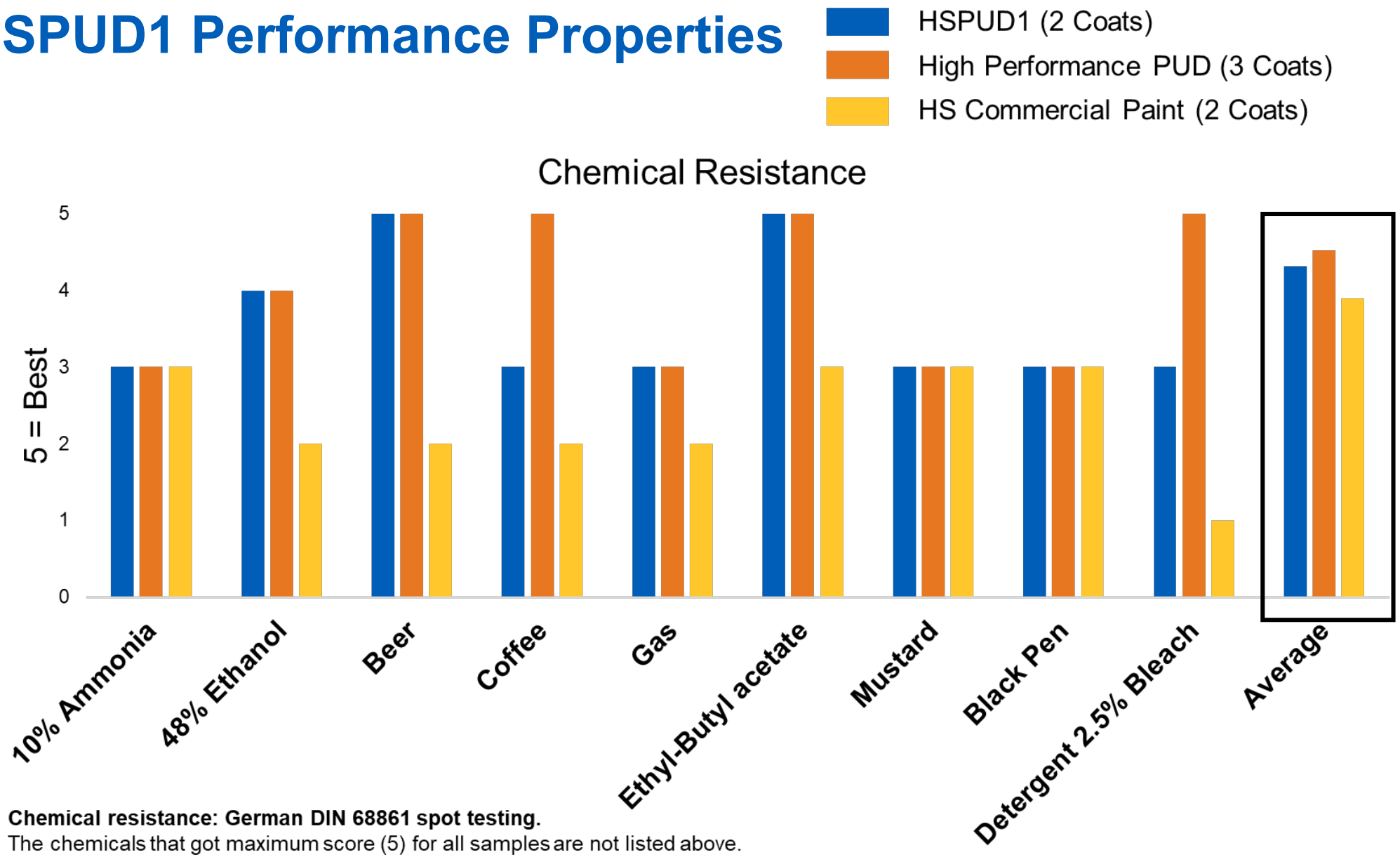
Appearance (wet)	Water white
Total Solids by Weight, %	50.0 ± 1.0
Density (lb./gal. @ 25°C)	8.76
Neutralization	TEA, 0.95%
Brookfield Viscosity, cPs	< 500
Stability	1 year
Formulated Solids by Weight, %	40.6
EU VOC, g/L (ISO 11890-2)	100
US VOC, g/L (EPA Method 24)	209

High solids are achievable in PUD based formulations

HSPUD1 Performance Properties



HSPUD1 Performance Properties



Chemical resistance: German DIN 68861 spot testing.
The chemicals that got maximum score (5) for all samples are not listed above.

2nd Generation High Solids PUD – HSPUD2

High Solids Carboxyl Functional PUD Designed for Carbodiimide Crosslinking

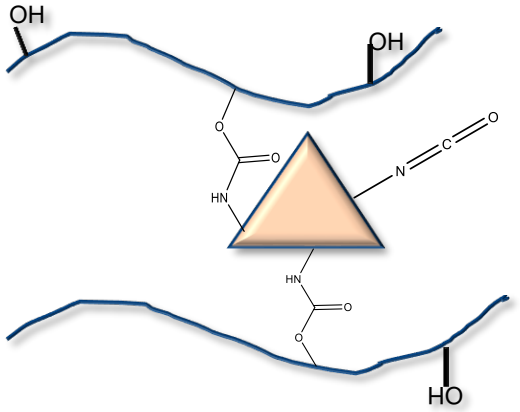
Appearance (wet)	Water white
Total Solids by Weight, %	45.0 ± 1.0
Density (lb./gal. @ 25°C)	1.02
Neutralization	TEA-Free
Brookfield Viscosity, cPs	<100
Stability	1 year
Formulated Solids by Weight, %	40.6
EU VOC, g/L (ISO 11890-2)	40
US VOC, g/L (EPA Method 24)	100

Performance without the need for hazardous crosslinkers

HSPUD2 – Alternative Crosslinking

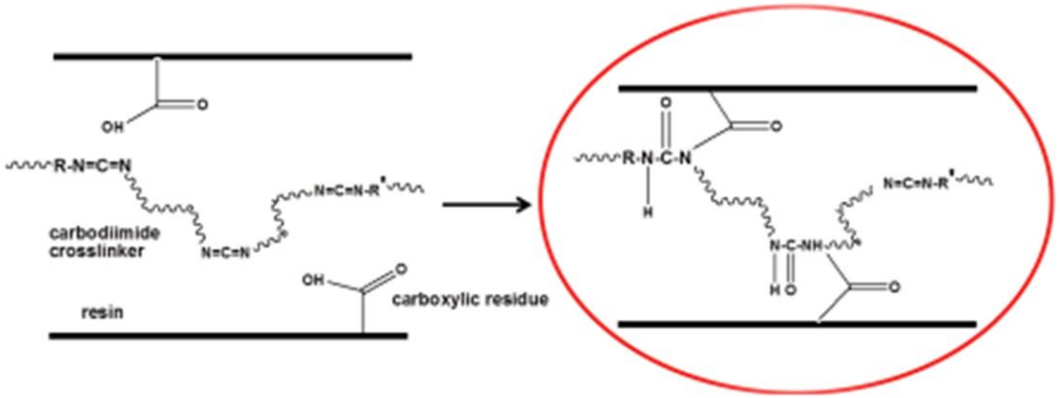
ISOCYANATE CROSS-LINKING

- Reacts with hydroxyl groups
- High reactivity/performance
- Hazardous identification



CARBODIIMIDE CROSS-LINKING

- Reacts with carboxyl groups
- Environmentally friendly: Low Toxicity
- Moderate performance improvement: Poor reactivity



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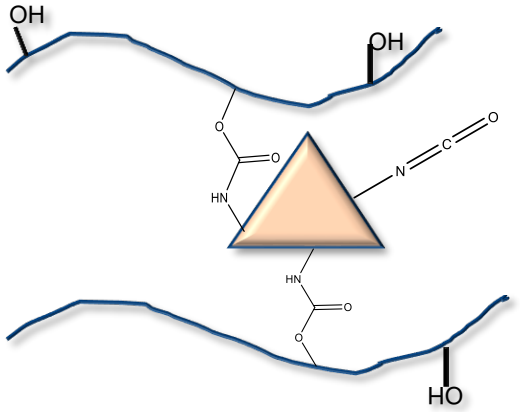
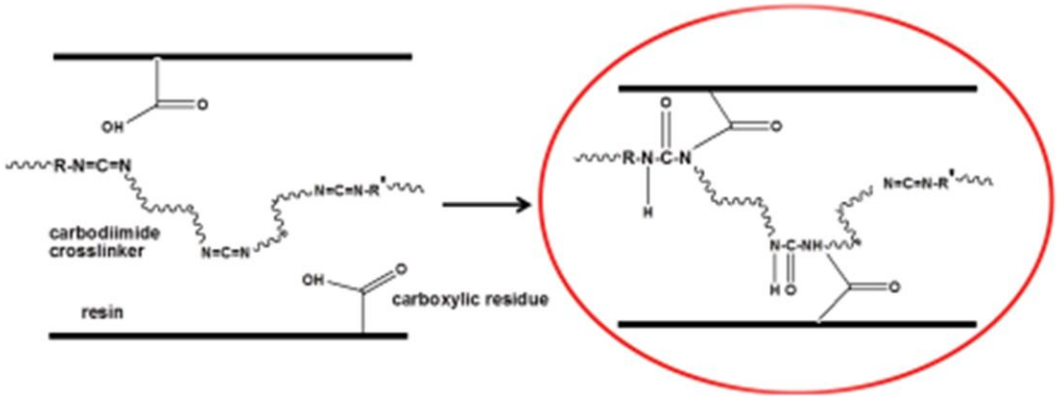


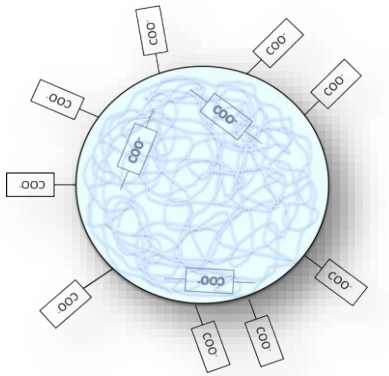
CARBODIIMIDE CROSS-LINKING

- Reacts with carboxyl groups
- Environmentally friendly: Low Toxicity
- Longer Pot life



Optimized urethane **MORPHOLOGY**

- Reduction/elimination of hazardous components: Isocyanate Crosslinkers
- Performance: Improved crosslinking efficiency with carbodiimides
- Film formation at low temperatures: Lower VOC

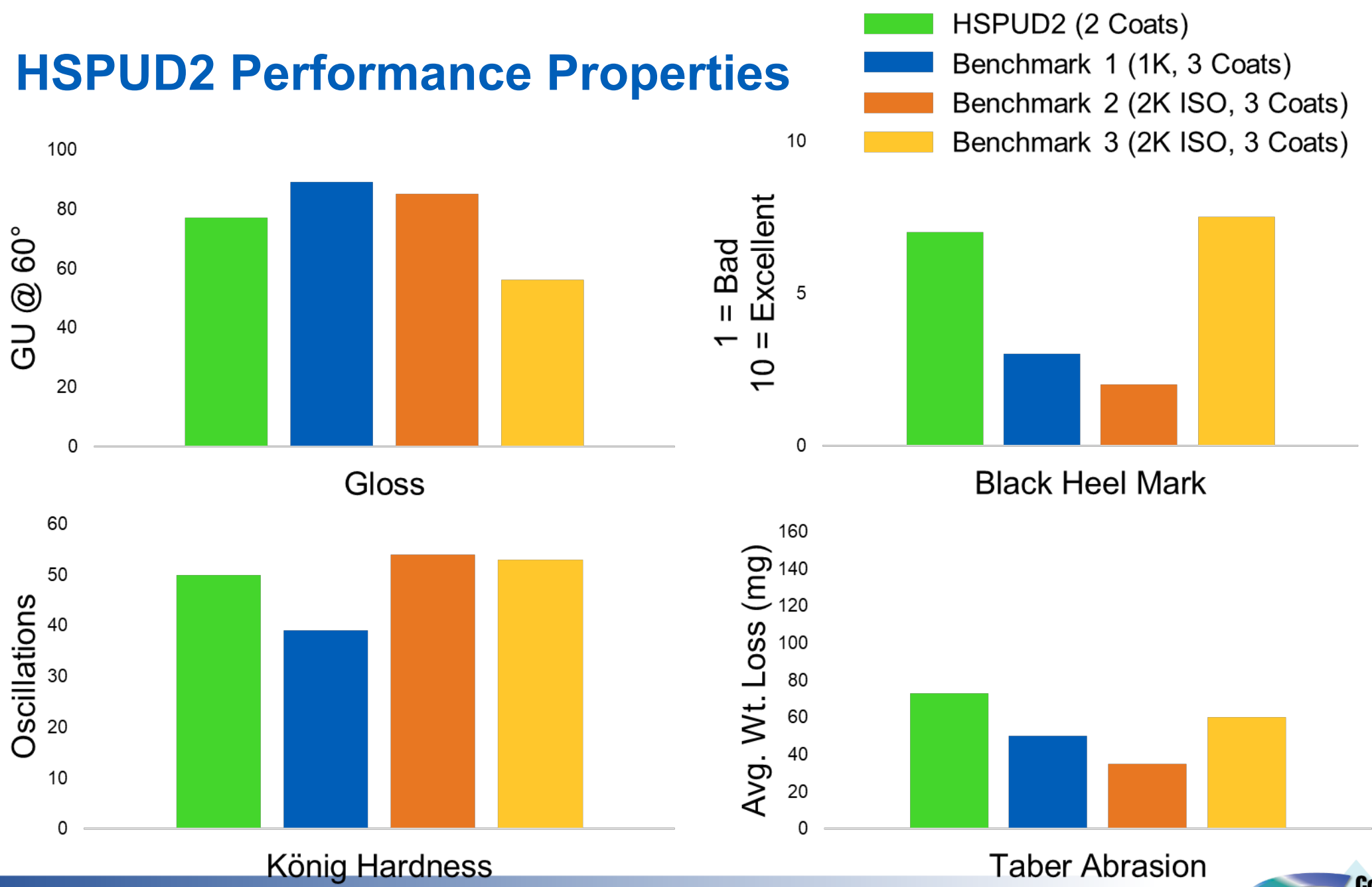


HSPUD2 Performance Properties

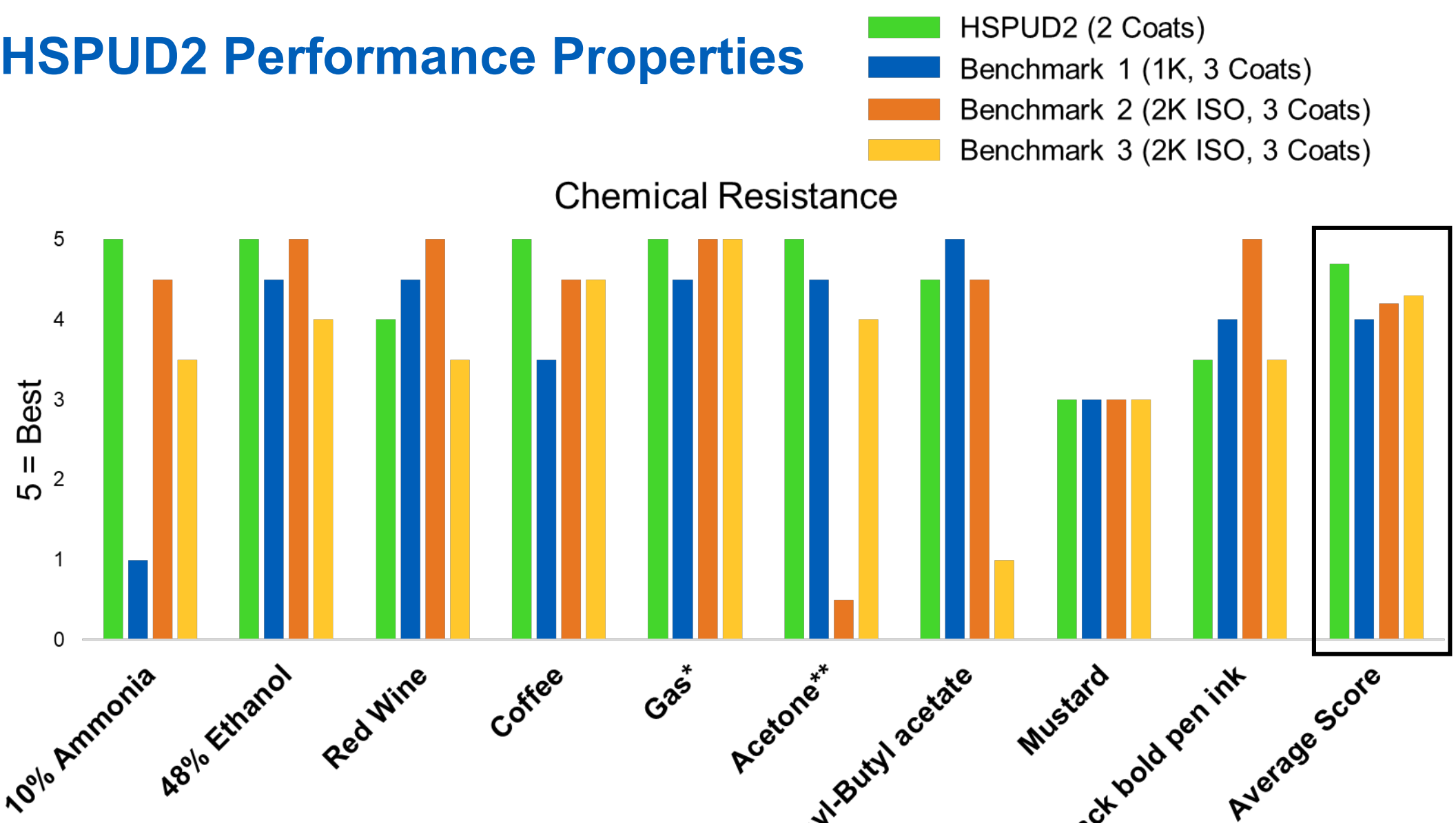
Samples	System	Crosslinker	US VOC (g/l, EPA method 24)	EU VOC (g/l, ISO 11890-2)	# of Coats
HSPUD2	**2K**	**Carbodiimide**	**100**	**40**	**2**
Commercial Benchmark 1	1K	N/A	140	46	3
Commercial Benchmark 2	2K	Isocyanate	288	130	3
Commercial Benchmark 3	2K	Isocyanate	230	85	3 (2 + primer)

Lower VOC and Fewer Coats

HSPUD2 Performance Properties



HSPUD2 Performance Properties



Chemical resistance: German DIN 68861 spot testing.
The chemicals that got maximum score (5) for all samples are not listed above.

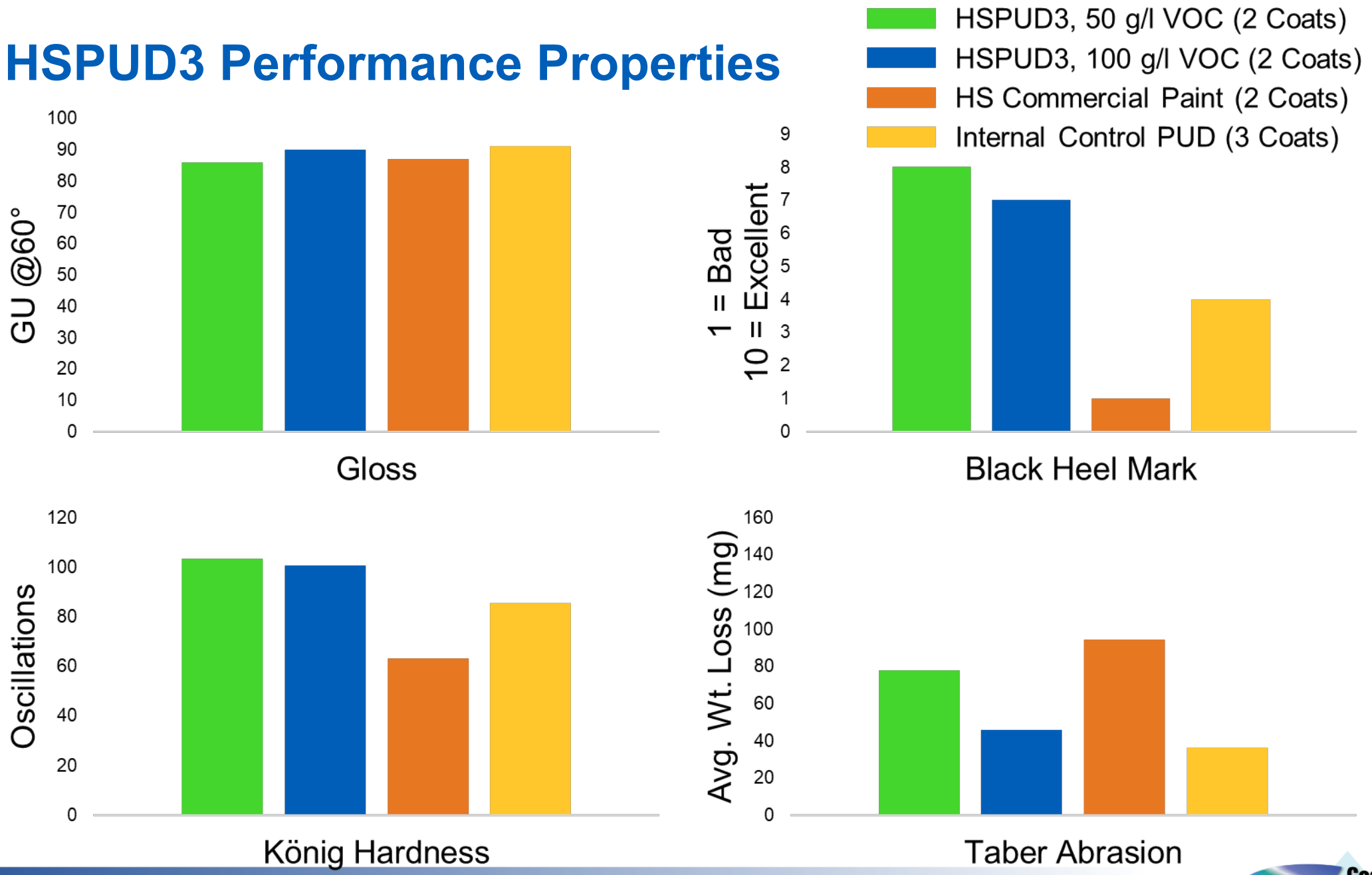
3rd Generation High Solids PUD – HSPUD3

High Solids Self-Crosslinking Low VOC TEA-Free Polyurethane Dispersion

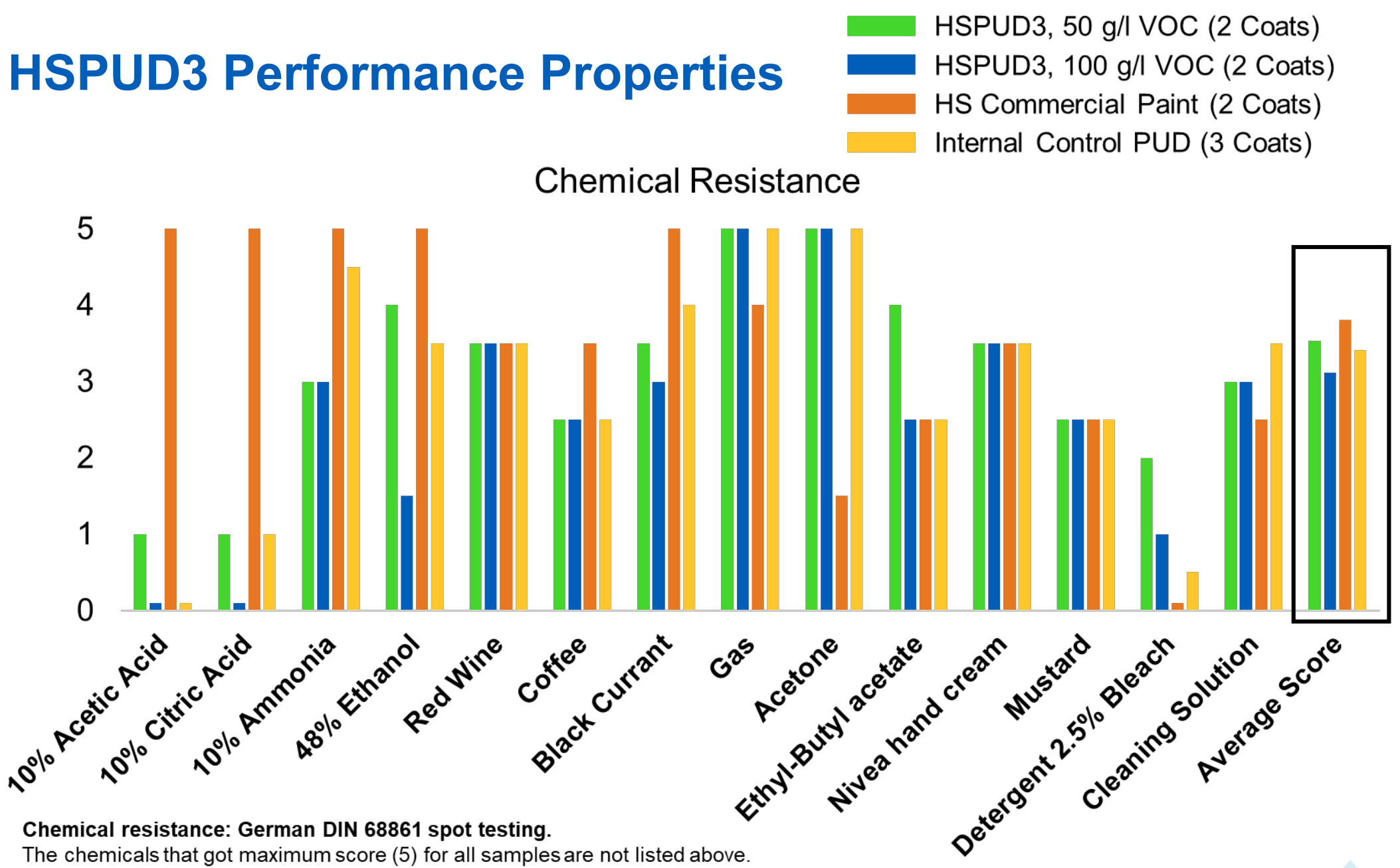
Appearance (wet)	Water white	
Total Solids by Weight, %	50 ± 1.0	
Density (lb./gal. @ 25°C)	1.04	
Neutralization	TEA-Free	
Brookfield Viscosity, cPs	<400	
Stability	1 year	
	Formula 1	Formula 2
Formulated Solids by Weight, %	40	40
EU VOC, g/L (ISO 11890-2)	40	20
US VOC, g/L (EPA Method 24)	100	50

High Solids with low VOC

HSPUD3 Performance Properties



HSPUD3 Performance Properties



Chemical resistance: German DIN 68861 spot testing.
The chemicals that got maximum score (5) for all samples are not listed above.

Conclusions

High Solids PUDs can provide…


Freight and packaging savings


Improved productivity and better application efficiency


CO_2 emission reduction – freight and manufacturing


Removal of hazardous chemicals (TEA, isocyanate crosslinkers)


Low VOC


High chemical resistance and mechanical properties

Questions?

Thank You!