Development of Sustainable Engineered Biopolymers in Wood Composite

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WHO WE ARE
WHAT WE DO

We are a chemical company and we transform industries toward sustainability by offering a range of engineered biopolymers for targeted markets which enable profitable growth for our customers.

EcoSynthetix

OUR VISION

To be one of the world's leading technology and market developers of bio-based materials.

Through value-added substitution of ageing fossil-based materials our enterprise will benefit society as a result of our sustainable technology, created from green chemistry and delivering a reduced carbon footprint.

EcoSynthetix

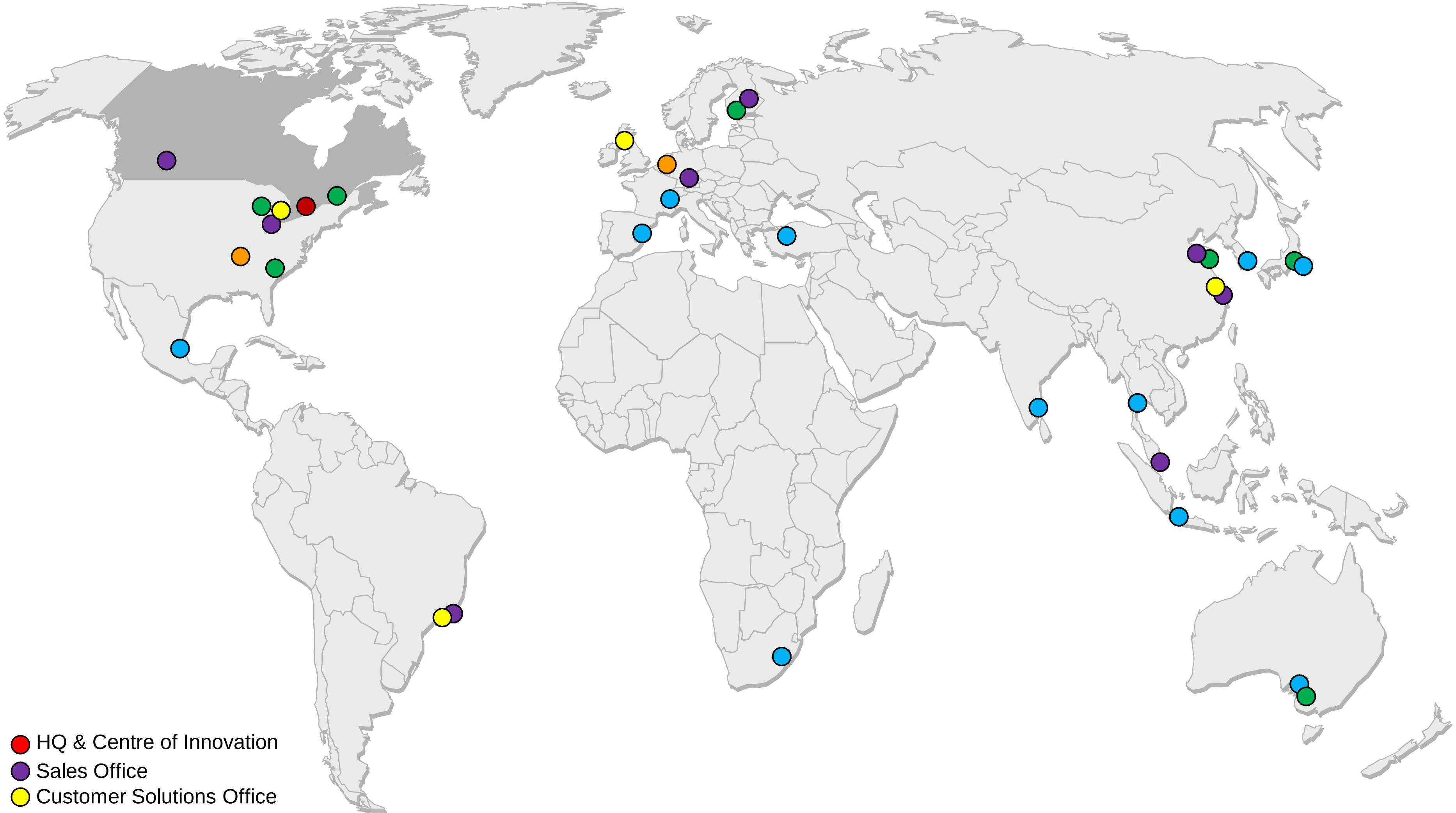
A Growth-oriented Company

ECOSYNTHETIX®

SUSTAINABLE POLYMERS FOR PLANET EARTH™

Enhancing Nature's Best	Adding functionality - tailored to overcome the challenges of fossil fuel based materials
Viable and practical	Compatible with incumbent technologies, economically positive
Global Reach	Manufacturing, distribution, customer support in over 20 countries
Experienced Team	Global and local experienced industry team

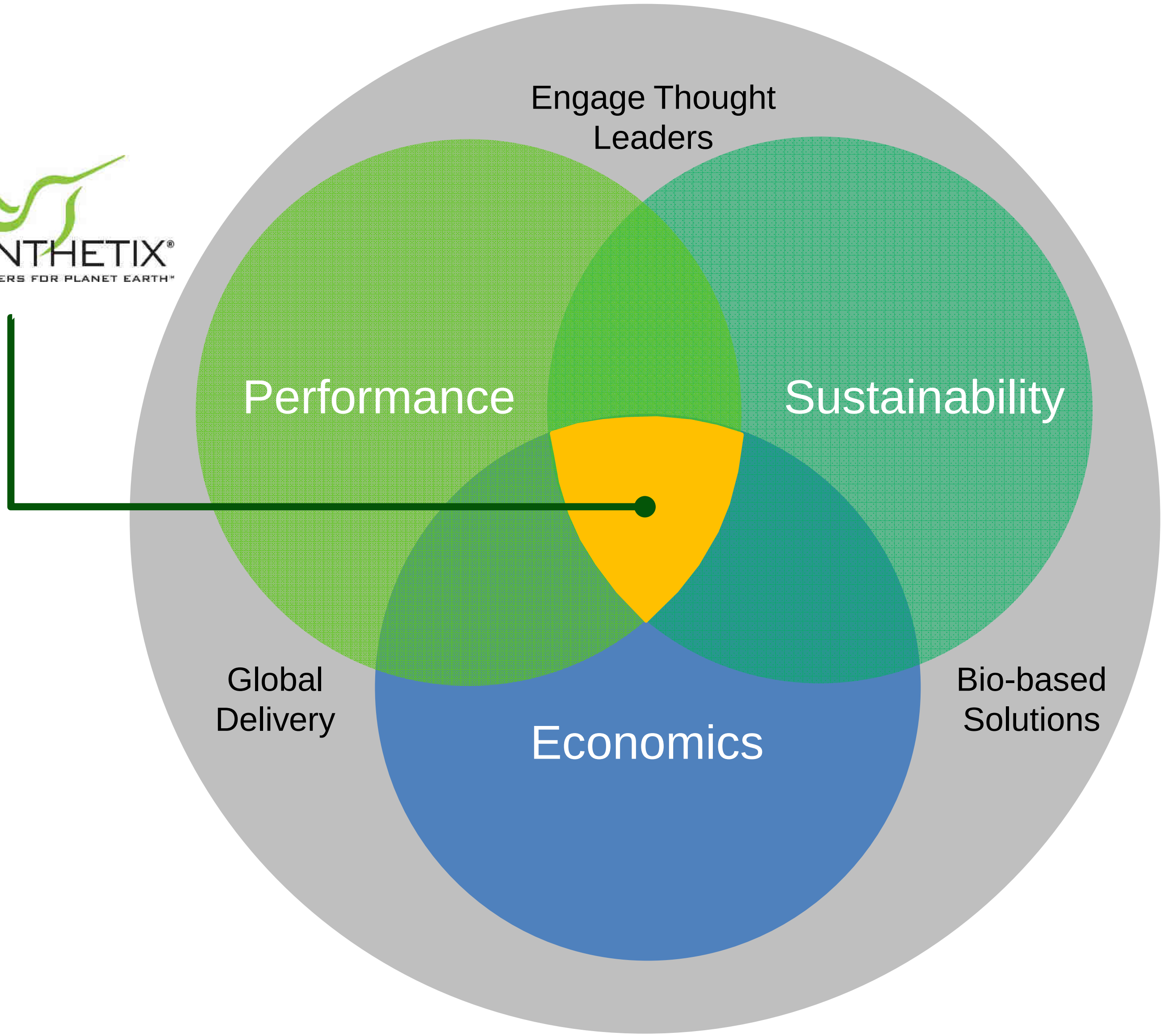
Global Operations with Local Expertise



- HQ & Centre of Innovation
- Sales Office
- Customer Solutions Office
- Distributor/Agent
- Dispersion Facility
- Manufacturing Facility

Environmentally Sustainable Products Require Also Compelling Value Proposition

ECOSYNTHETIX®
SUSTAINABLE POLYMERS FOR PLANET EARTH™



Applying Green Chemistry to Match or Exceed Performance in Many Products

Transitioning from
SB Latex in
Paper & Board

Consumer Benefit:
Sustainable Packaging

Manufacturer Benefit:
Safer Chemicals,
Sustainability &
Economics

Transitioning from
Formaldehyde & pMDI
in Wood Composites

Consumer Benefit:
Low to zero VOC

Manufacturer Benefit:
Safer Chemicals, C2C
& Sustainability

Transitioning from
Formaldehyde
in Building Insulation

Consumer Benefit:
Low to zero VOC

Manufacturer Benefit:
Safer Chemicals &
Sustainability

Transitioning from
Glass-filled PP in
Automotive

Consumer Benefit:
Natural Ingredients

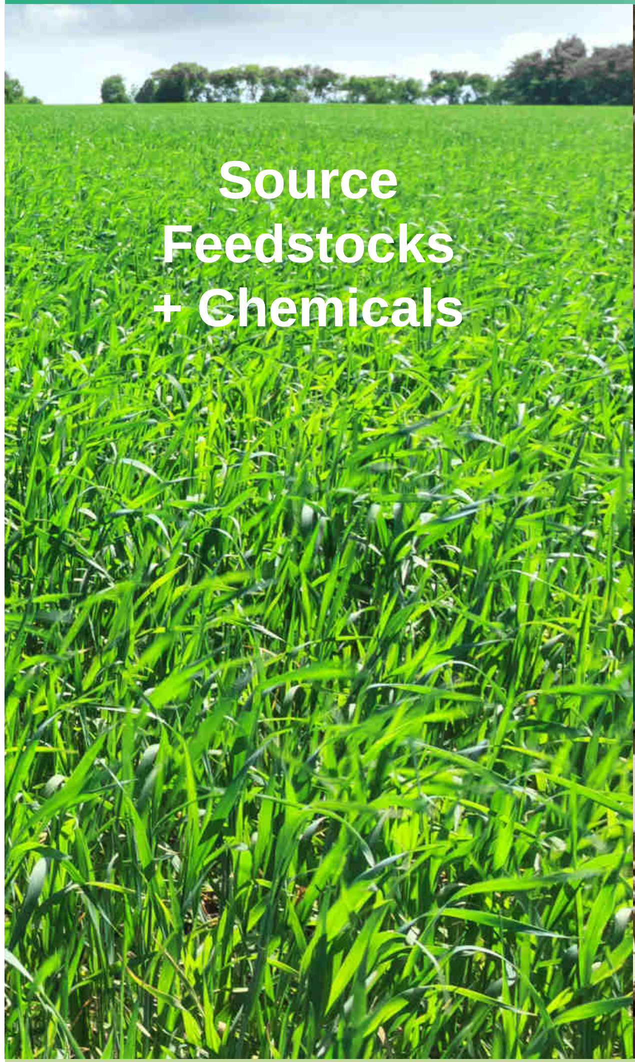
Manufacturer Benefit:
Sustainability & C2C

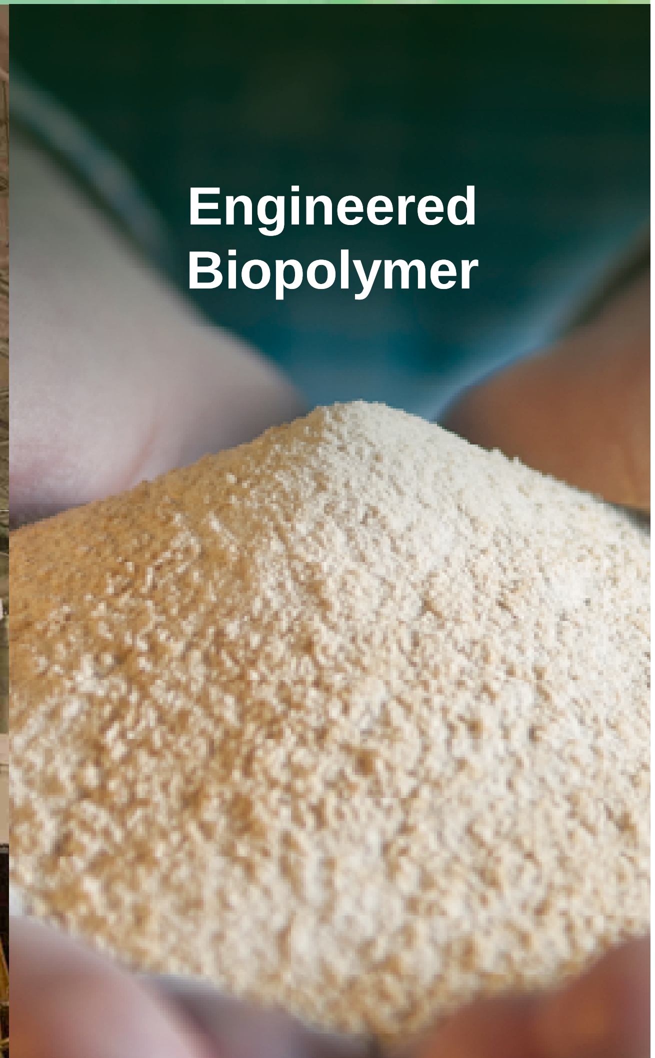
Transitioning from
synthetic binders in
Nonwovens

Consumer Benefit:
Natural Ingredients,
Biodegradability

Manufacturer Benefit:
Sustainability & C2C

Unique Processes and Technologies





Patented Formula → Patented Process → Patented Product

EcoSynthetix® Engineered Biopolymers

Biopolymers

- Proteins
- Sugars
- Starches
- Cellulose
- Tannins
- Other Carbohydrates

ENGINEERED Biopolymers

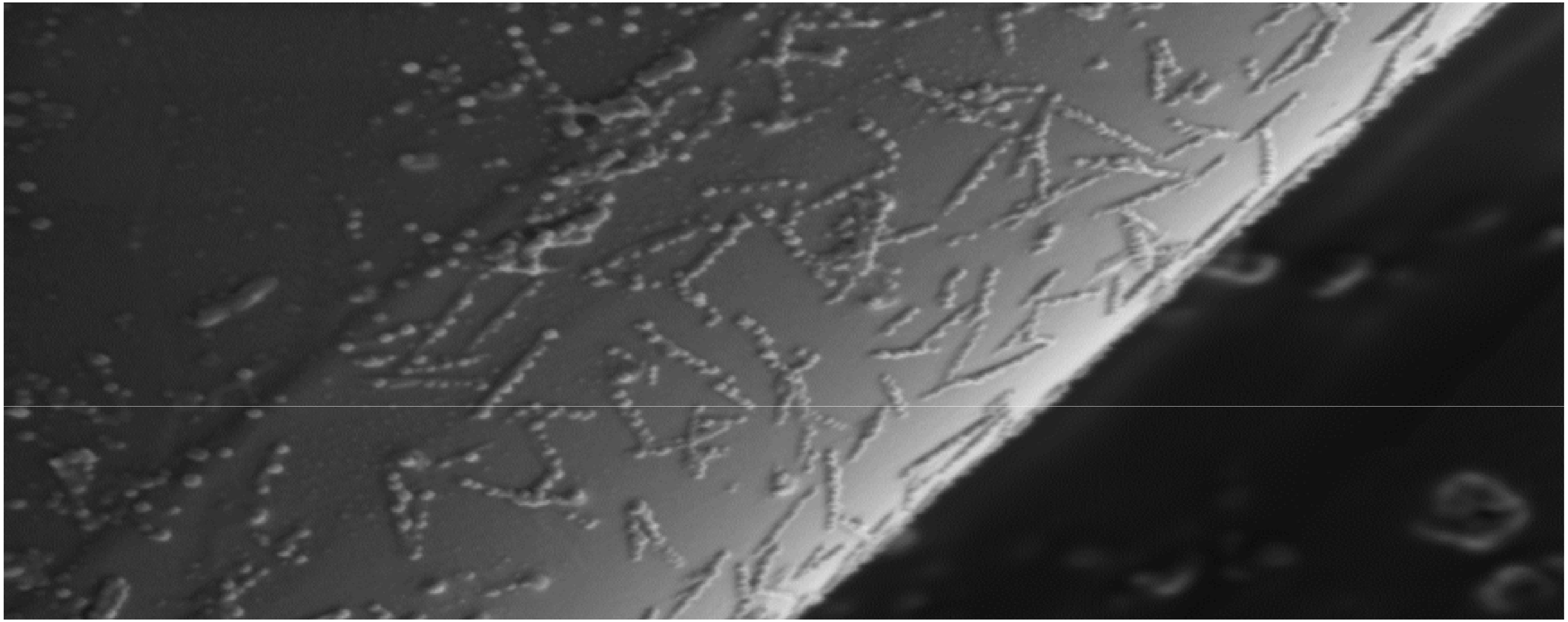
- **New chemical architecture**
- **Similar to synthetic polymers**
- **Example: Durabind™**

Critical To Quality

- **Mechanical**
- **Moisture**
- **Emissions**
- **Economics**
- **Supply**
- **Processing**

Engineered biopolymers are tailored for specific applications and replace many synthetic chemistries.

Biopolymers of Nanoparticle Scale



- One litre of aqueous dispersion at contains roughly $1x10^{18}$ particles which translates to a surface area ~40,000 m^{2}.
- **This expansive surface potential translates to greater coating efficiency and increased binding mechanics**.

The Challenge in Wood Composites

- **Formaldehyde is inherent in wood but added formaldehyde can be a significant problem**
- The majority of binder systems employed today are based on formaldehyde emitting resins
- Increasingly, legislation is being implemented that greatly restricts the addition of formaldehyde
- Balancing cost and meeting tough new legislation is a major challenge to our industry

- **EcoSynthetix® Durabind™ system delivers cost savings and performance that meets the challenge!**

DuraBind™

- **DuraBind™** is the environmentally friendly, bio-based system that eliminates added formaldehyde in wood composites
- **DuraBind™** systems are targeted to be cost neutral vs the incumbent and performance comparable with existing technologies
- **DuraBind™** goes beyond NAF and binder cost with numerous added value benefits

The DuraBind™ System

- **DuraBind™ Bio-Urethane Chemistry**
  - Tailored mixture of Engineered Biopolymer and Cross-linker
  - Targeted to be cost neutral versus UF System
  - Lower cost versus pMDI

- **DuraBind™ Process Enhancements**
  - Application technology
  - Process stability

- **DuraBind™ Renew technology**
  - Enabling technology to reuse “squeeze” and other excess process water
  - Empowering scavenger to allow recycling of wood from any binder source

Successful Trials Confirm DuraBind™ System

Compelling value proposition	✓	Saving money
Chemistry is easy to handle and safer than alternatives	✓	No new regulatory
No issues getting the binder into the process	✓	Used existing equipment
Make boards At the same processing conditions With no visual defects	✓	Multiple extended trials with multiple customers
Confirmation that DuraBind boards are being sold through customer's normal process	✓	Meeting specifications

DuraBind™ Benefits- Lab Results

	UF	pMDI	DuraBind™
Binder loading, %	10	3	3
Density, kg/m3	664	678	668
I.B., N/mm2	0.55	0.53	0.52
M.O.R., N/mm2	12.0	14.2	16.8
M.O.E., N/mm2	2406	2250	2501
2h T.S., %	30.7	6.7	5.3
2h W.A., %	55	17	13
24h T.S., %	53.5	46.2	33.3
24h W.A., %	97.9	100.8	76.9
Moisture content of board (%)	6.7	6.2	6.4
Formaldehyde content (mg/100g)	6.2	2.5	1.8
Gas Analysis value (mg/m²/h)	**2.8**	**2.0**	**1.2**

- Enhancement of board performance
- Significant reduction in formaldehyde emissions

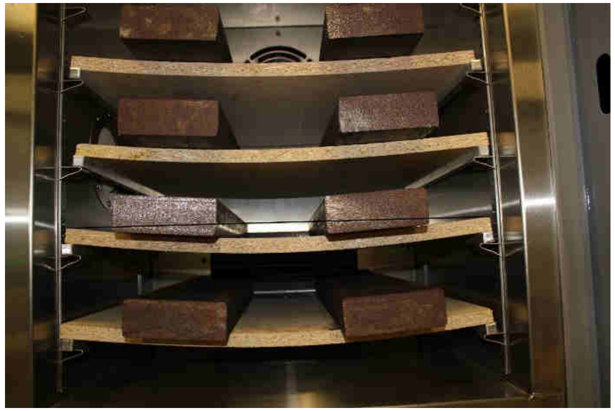
DuraBind™ Benefits- Industrial application

Sample (8mm flooring MDF)	Control (2.7% pMDI)	DuraBind™ (2.7% loading)
Density	846	834
MOR (N/mm2)	42.5	41.7
IB (N/mm2)	2.5	2.3
2h TS	12.4	10.7
24h TS	22.3	22.3
2h WA	19.2	18.0
24h WA	34.3	35.2

Confidence on commercial board performance

DuraBind™ Benefits– Accelerated aging test

- Evaluation of changes in mechanical properties over 3 cycles:
  - **Cycle 1: 1 week at 23 °C and 50 % RH**
  - **Cycle 2: 3 weeks at 28 °C and 85 % RH**
  - **Cycle 3: 2 weeks at 28 °C and 25 % RH**



	Radius of curvature (cm)			
Stage	**Initial**	**Cycle 1**	**Cycle 2**	**Cycle 3**
UF Control	**703 ± 70**	**568 ± 123**	**187 ± 1**	**167 ± 1**
DuraBind™	**717 ± 73**	**510 ± 33**	**188 ± 1**	**168 ± 2**

- Mechanical properties are similar to control UF boards

The DuraBind™ Renew Technology-Added Value

- **DuraBind™ Renew technology**
  - Enabling technology to reuse “squeeze” and other excess process water/ waste water

- **Tailored solution for each individual plants**

- **Benefits:**
  - Cost saving
  - Sustainability

DuraBind™ Added Benefits
Turning Waste Water into Sellable Boards

Waste water from MDF refiner process

Brown suspension

Waste Water Treatment

<u>Current Options:</u>

1) Treatment
2) Incinerate
3) Tanker Disposal Off-site

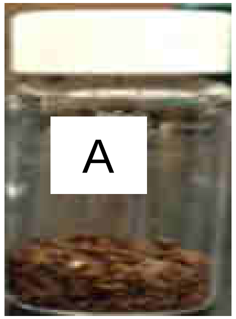
<u>Off Site Disposal Cost</u>

As much as $0.30 / liter
~ $6,000 a tanker and
> $20,000 / week in peak times

DuraBind™ Added Benefits
Waste Water Analyses

Sample A Wastewater

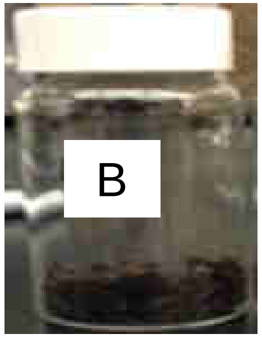
Appearance: Light brown suspension
Initial pH: ~4.5



Composition: Mostly Softwood Extractives

Sample B Wastewater

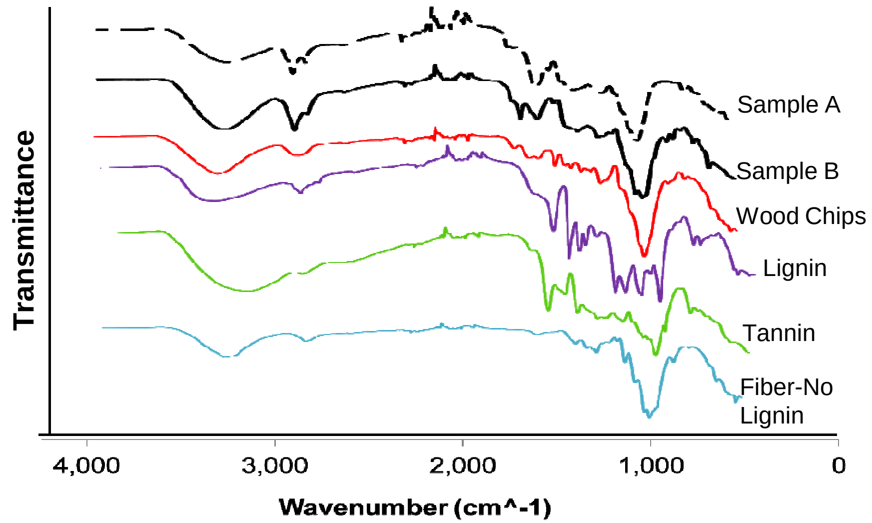
Appearance: Dark brown suspension
Initial pH: ~4.75

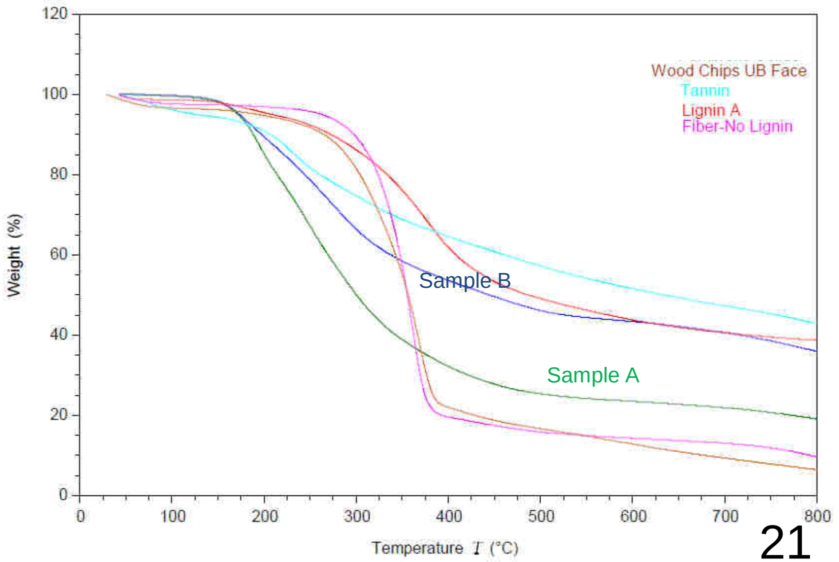


Composition: Mostly Hardwood Extractives

DuraBind™ Added Benefits
Waste Water Analyses-FTIR and TGA

- Strong buffering characteristics
- Both samples exhibited –CH2 functionalities which represent lipid extractives that account for 40-60% of extractives in softwood (Sample A) and 60-90% of extractives in hardwood (Sample B)
- Characteristic softwood extractives were observed in the Sample A such as ketones, aldehydes and that account for 40-45% of softwood extractives





DuraBind™ Added Benefits
Turning Waste Water into Sellable Boards

Pounds of DuraBind™ Used Annually	Gallons of Potential Waste Water Reused	Number of Tanker Trucks at 40,000 lb. per Tanker
7,000,000	1,625,000	**325**
4,900,000	1,137,500	**228**
3,500,000	812,500	**163**
1,400,000	325,000	**65**

Save Money
With Less Waste

Make Boards
At Lower Cost

DuraBind™
Binder System
Benefits

Compelling Value for UF users

- **Million dollars savings potential on an annual basis**

- **Binder cost comparison**:
  - DuraBind™ binder is targeted to be cost neutral versus a typical UF system - **<u>10% UF loading = 3% DuraBind Bio-Urethane</u>**

- **Reduction of UF systems added cost**
  - Emission testing
  - Internal plant environment testing
  - External emissions
  - Waste water disposal
  - Yield loss for out of specification

  Independent industry report shows cost at **$0.5 to over $1.0 million annual cost** to manage towards CARB II

- **Lower transport cost**
  - 1/3 of current shipping

Compelling value for pMDI users

- **Million dollars savings potential on an annual basis**

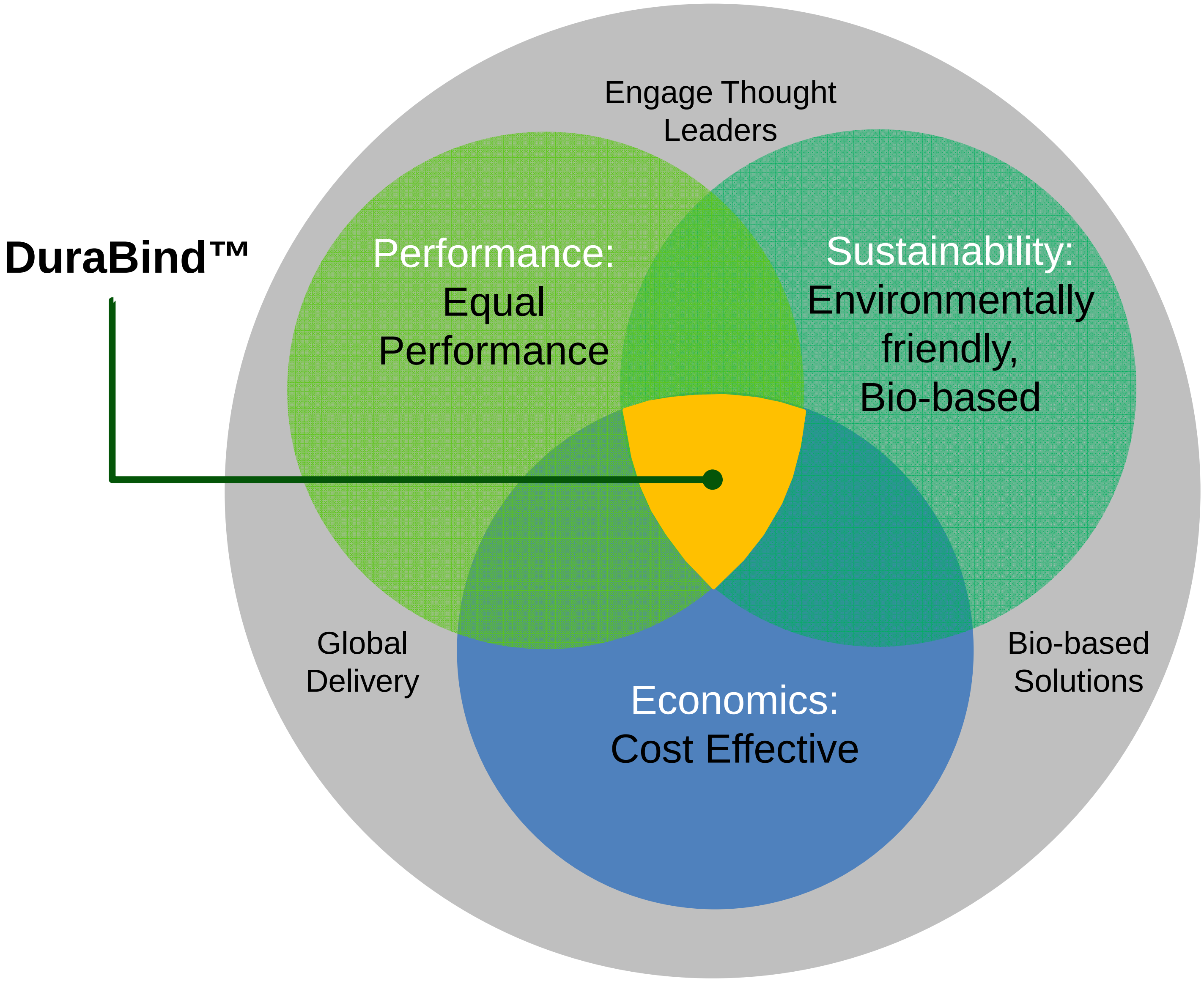
Internal Benefit:

- Improved economics versus pMDI
- Reduced release agent use
- Lower process contamination and clean up
- Significant additional savings
  - Reuse of “squeeze” water or wood

Customer Benefit:

- Improved machining quality at customer
- Less tool and press wear at customer
- Lower claims and rejects at customer

DuraBind™- Summary

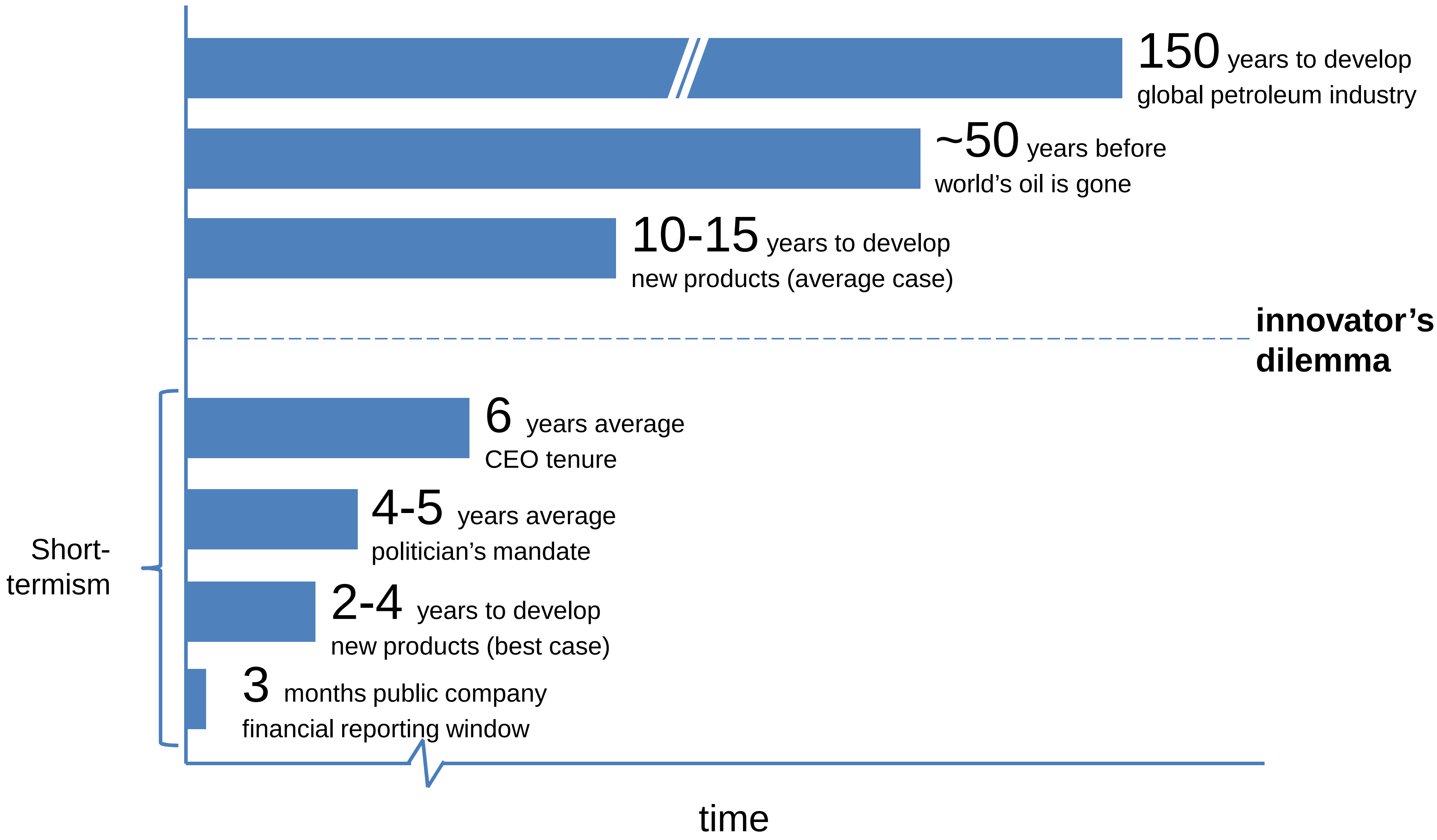


Thank you

CHIMAR

ECOSYNTHETIX®
SUSTAINABLE POLYMERS FOR PLANET EARTH®

“Short-termism”



What do we mean by sustainable ?

"***a system that maintains its own viability***"

Environmental	– Using natures strength to enhance
Viability	– Practical and long lasting
Cost effective	– Direct and indirect benefits

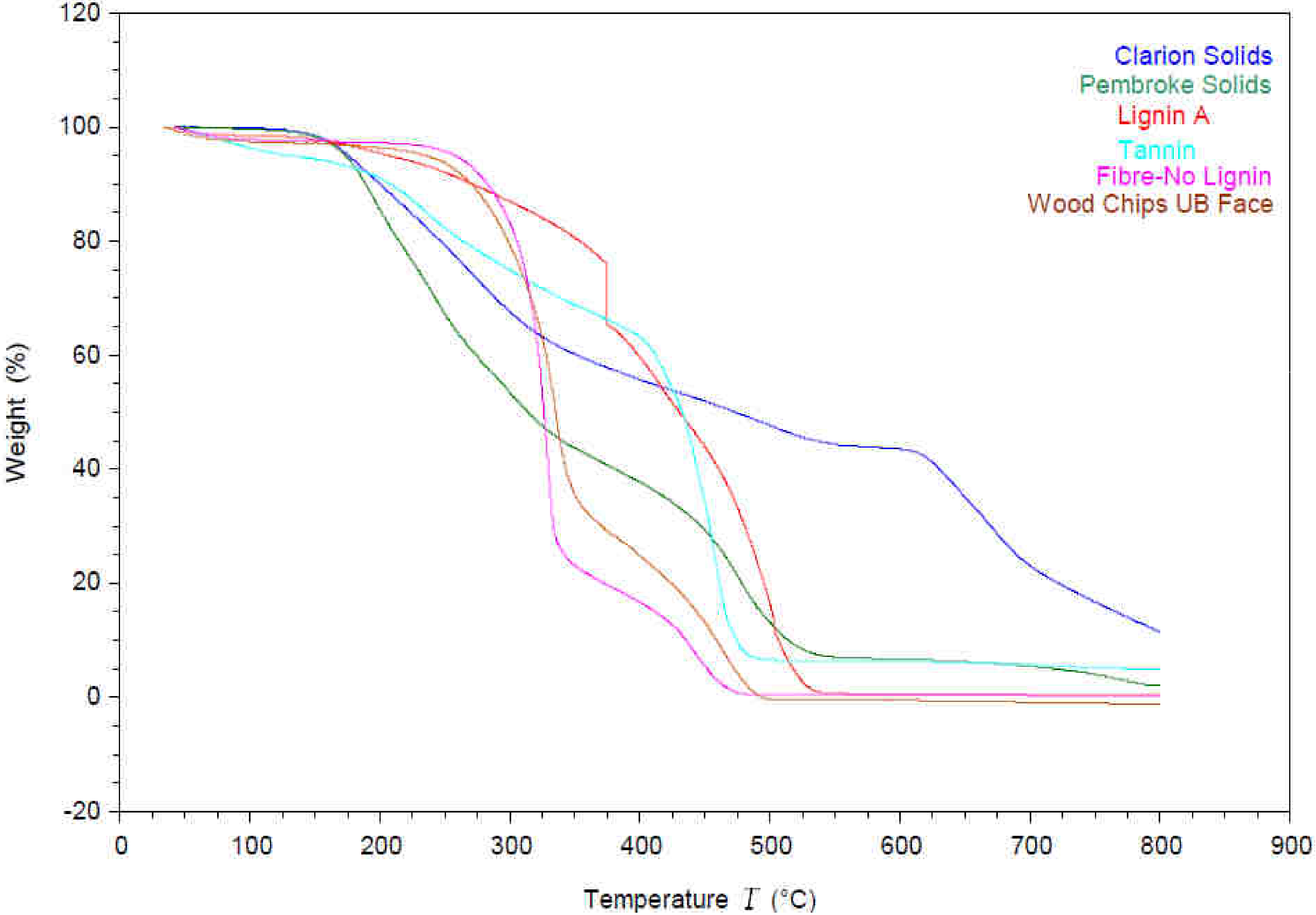
FTIR Peak Assignments

Wavenumber (cm^{-1})	Functional Groups
3300	-OH
2900	$-CH_2$
1730	Ester carbonyl
1690, 1602	Conjugated carbonyl structure
1580, 1513, 1220	C=C, C-O bending and stretching, in aromatic groups (Lignin or extractives)
1450	$-CH_3$ bending in lignin or hemicellulose
1446	C=C in aromatic ring, CH3, CH2 asymmetrical stretching
1375, 1020	C=O, C-H, C-O-C, C-O, deformation or stretching variation in carbohydrates
1360, 850	Syringyl (S) ring plus guaiacyl (G) ring, C–H out-of-plane in position 2 and 6 of S units
1212, 1260	CO stretching in lignin or hemicellulose
1201	C-O-C symmetric stretching
1160	C-O-C asymmetric stretching
1126, 1030	Aromatic C-H in-plain formation from the syringyl unit
975	C-H out-of-plane stretching
850	Aromatics

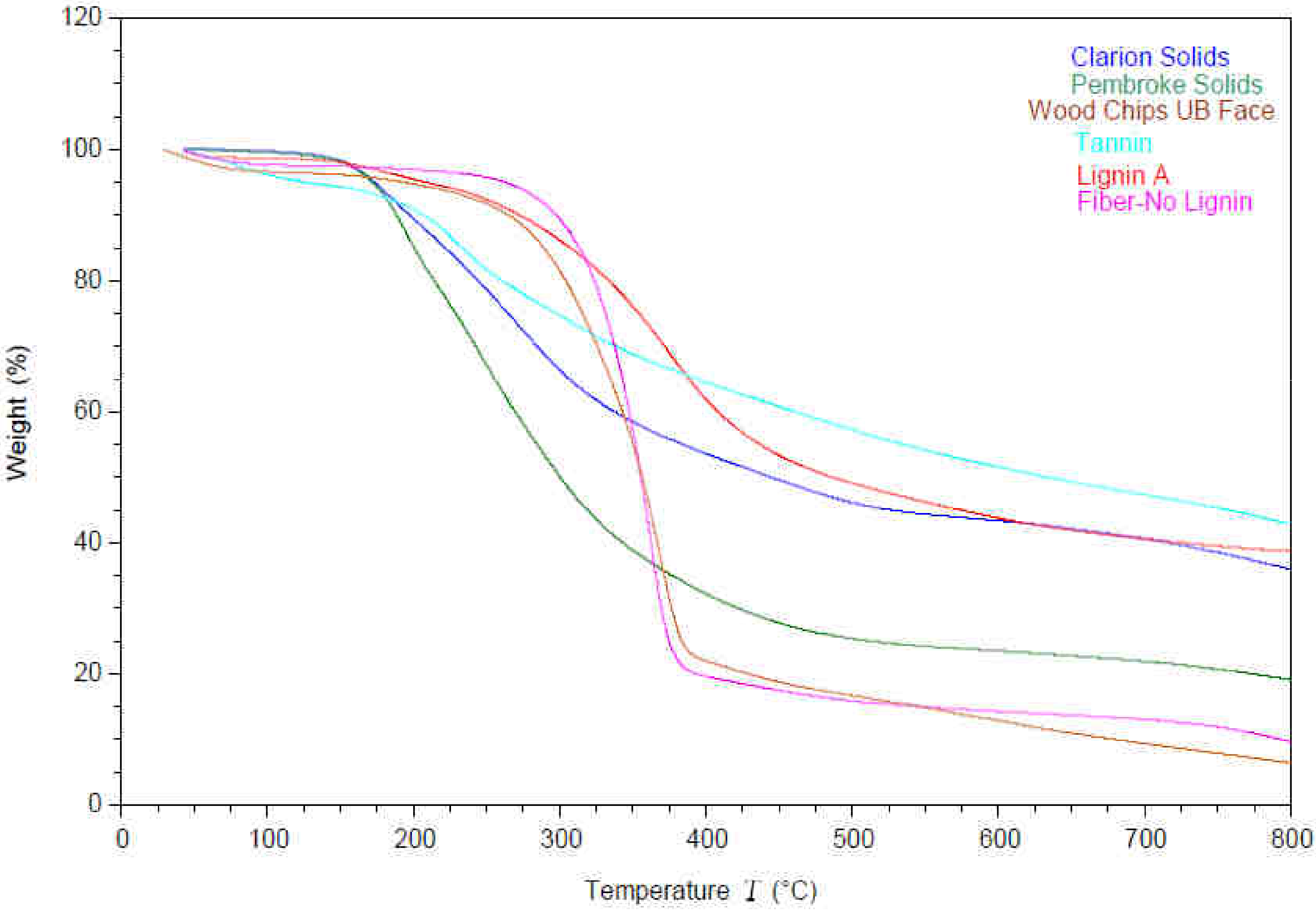
FTIR Analysis Conclusions

- Peak differences between the two wastewater solid samples show that their compositions are different
- Both Clarion and Pembroke displayed C=C, C-O bending and stretching, in aromatic groups, showing the possibility of extractives and/or lignin present and C=O, C-H, C-O-C, C-O, deformation or stretching variation, which is present in carbohydrates
- Characteristic softwood extractives were observed in the Pembroke solids by conjugated carbonyl groups, which represent ketones, aldehydes and resin acids that account for 40-45% of softwood extractives, which correlates to the pine smell. These resin acid extractives are not as prominent in hardwoods and since this peak was not in the Clarion solids the wastewater from Clarion is most likely from hardwood species.
- Both samples showed aromatic functionality peaks representative of phenolic functionalities (Lignin, Stilbenes, flavonoids, etc.)
- Clarion and Pembroke solids exhibited –CH_2 functionalities which represent lipid extractives that account for 40-60% of extractives in softwood (Pembroke) and 60-90% of extractives in hardwood (Clarion).
- Differences in the peaks between the solids, lignin, tannin & fiber show that the wastewater is mainly composed of extractives

Thermal Analysis in Air Conditions



Thermal Analysis in Nitrogen Conditions



Under nitrogen condition

Thermal Analysis Conclusions

- TGA confirmed the difference in the composition of the two wastewater solids
- Based on the thermal analysis comparison of the wood constituents to the solids the Clarion and Pembroke solids are mainly composed of wood extractives and not major wood components (cellulose, hemicellulose and lignin).
- Under nitrogen conditions the similarity in the ending percent weight between the Clarion solids, lignin and tannin shows that the Clarion solids contain many phenolic functionality extractives, much more so than the Pembroke solids
- pH buffering differences in the 2 wastewater samples can be attributed to these composition differences