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Advancing Possible

Advancing the Sustainability of SMC & BMC Composites

SPE Thermoset TOPCON

Thomas Ebeling

May 10

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About LyondellBasell

LyondellBasell is a strong, global company delivering outstanding performance

LEADING[1]

Producer of **polypropylene compounds** globally

Licensor of **polyolefin technologies** globally

Producer of **polyethylene** in Europe

Producer of **polypropylene** in Europe

Producer of **oxyfuels** in Europe and North America

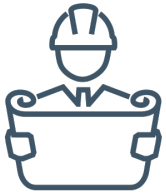
DIVERSE

The company's products, materials and technologies are **advancing sustainable solutions** for food safety, access to clean water, healthcare and fuel efficiency **in more than 100 international markets**.

GLOBAL

Every day, our **employees** work around the clock to safely **advance solutions** to our world's biggest challenges.

GROWING



Improved reliability of our first world-scale ***Hyperzone*** **HDPE** plant

Expanded in China with **integrated cracker JV** and **PO/SM JV**

Expanded in North America with **Louisiana Integrated PE JV**

Building the world's largest **PO/TBA** plant

Launched our ***Circulen*** portfolio of polymers that provide circular and sustainable solutions

As a leader in the global chemical industry, LyondellBasell strives every day to be the safest, best operated and most valued company in our industry.

(1) Source: LyondellBasell and IHS Markit. Note: Product rankings are as of December 31, 2021.

LyondellBasell has the scope and scale to serve global markets

Manufacturing sites & joint ventures in

21

countries

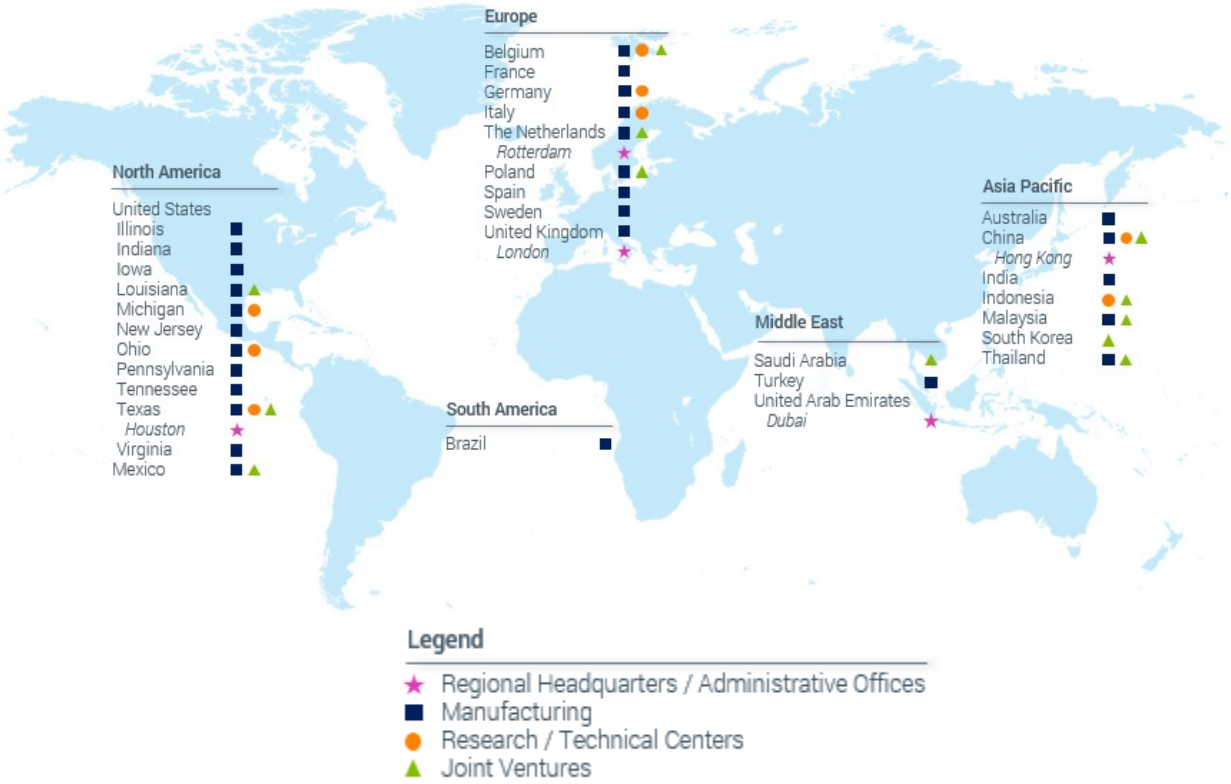
19,100

employees

Sales in

>100

countries



Note: Information as of December 31, 2021.

LyondellBasell delivers innovative products and solutions in five key areas

CHEMICALS

We produce the chemical building blocks for:

- Furniture / household goods
- Coatings / adhesives / cleaners
- Cosmetics / personal care products
- Industrial fluids
- Fuel additives

POLYMERS

Our versatile plastic resins are used to create a variety of products including:

- Rigid and flexible packaging
- Textiles
- Automotive parts
- Healthcare
- Pipe
- Agricultural films / irrigation

ADVANCED POLYMERS

Our diverse portfolio is used to create customizable products including:

- Automotive parts
- Differentiated packaging
- Electronics / appliances
- Building and construction materials
- Oil field services
- Aerospace
- Pipe
- Agriculture
- Wire and cable

FUELS

Our refinery in the U.S. produces:

- Gasoline / fuel components
- Low-sulfur diesel
- Jet fuel

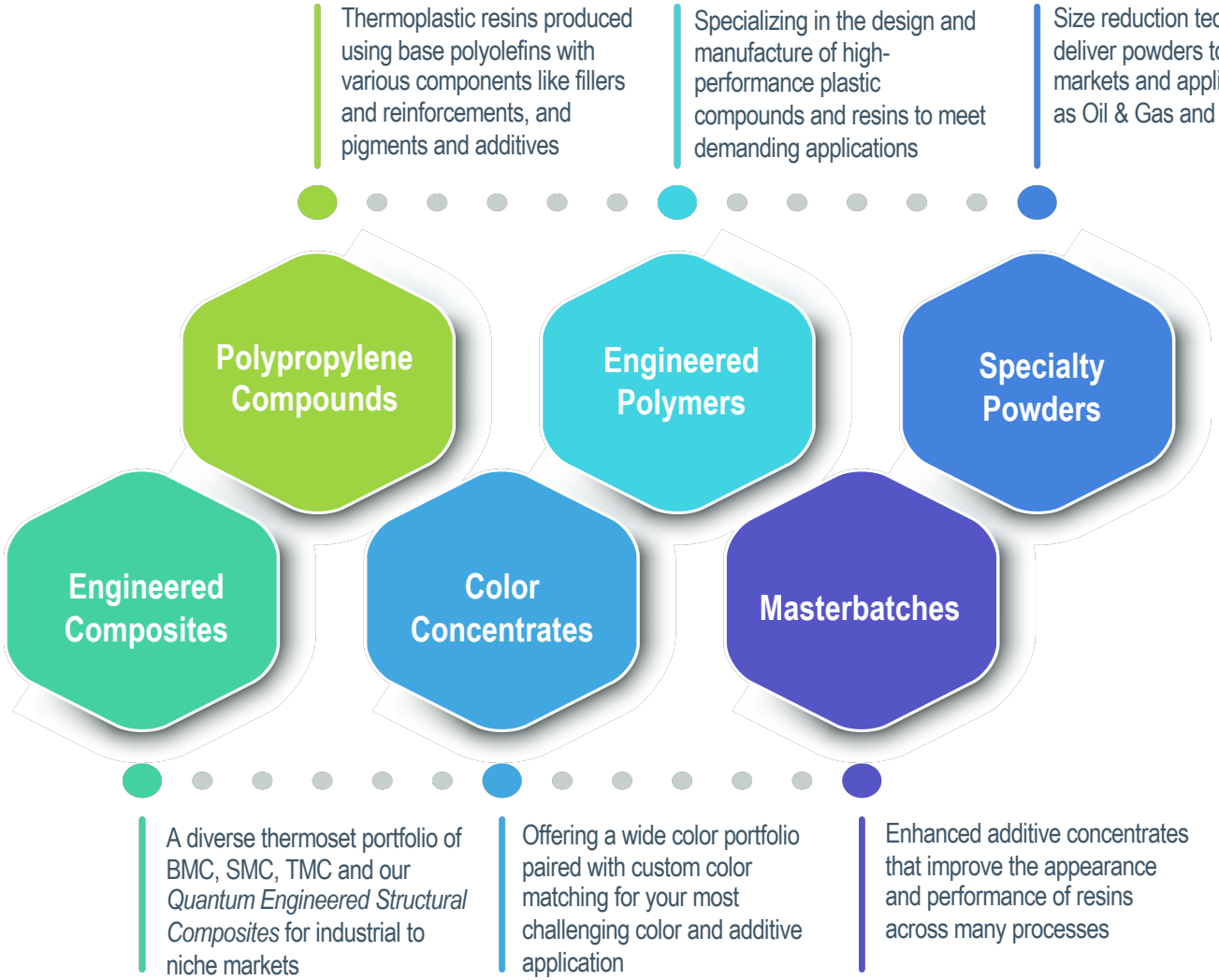
TECHNOLOGIES

We license our state-of-the-art manufacturing and process technologies:

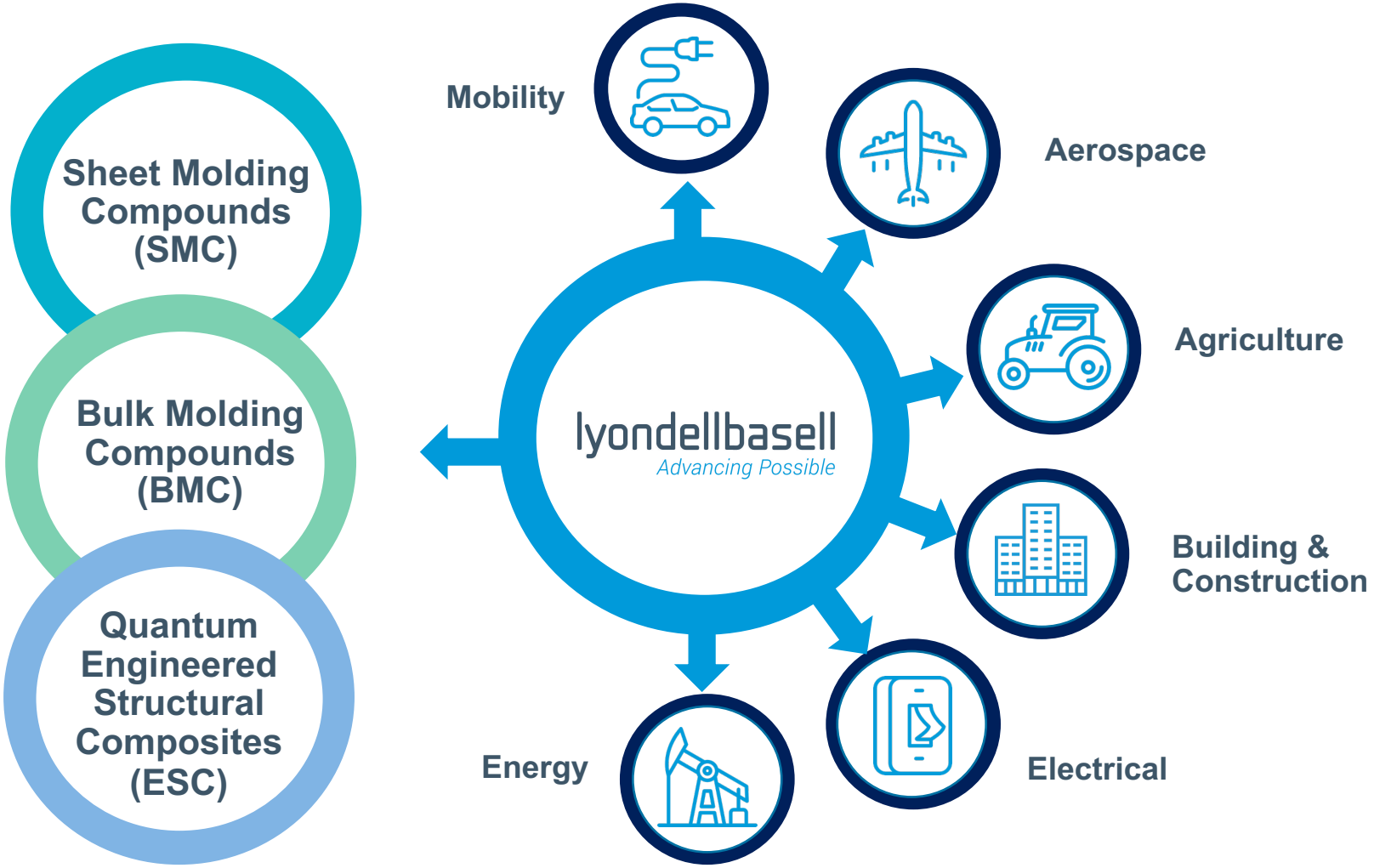
- Polyolefin catalysts
- Petrochemical process licenses

Advanced Polymer Solutions product portfolio

LyondellBasell delivers innovative solutions through our key material technologies:



Engineered Composites Division of LyondellBasell



Engineered Composites from LyondellBasell are transforming industries through a global portfolio dedicated to innovation and sustainability

Typical markets & applications

Engineered Composites

Automotive

- Forward Lighting
- Sensor Brackets
- Body Panels
- Liftgates
- Interior Trim
- Heat Shields

Building & Construction

- Electrical Boxes
- Circuit Breakers
- Wall Panels
- HVAC Housings
- Door & Window Skins
- Infrastructure

Energy

- Centralizers
- Frac Plug Components
- Valves
- Bipolar Plates
- Energy Storage

Aerospace & Defense

- General Aviation
- Military Aviation
- Tertiary Parts
- Secondary Structures

Heavy Duty Truck/ Agricultural

- Valve Covers
- Body Panels
- Oil Pans
- Throttle Bodies

Other

- Snowboard Bindings
- Helmets
- Small Appliances
- Structural Medical Devices
- Pump Housings

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Sustainability in the Composite World

Early Sustainability in Composite Materials

Early Weaponry

- Mongolian composite curved bow
- Japanese samurai sword

Early Aerospace

- Late 1930's – early 1940's: Gordon Aerolite
- Demonstration fuselage for Spitfire
- Phenolic and flax cured under pressure

Early Automotive

- 1941 Henry Ford "Soybean Car" concept vehicle
- Significantly reduced vehicle weight
- Soybean fiber in a phenolic resin

Historical Perspectives on Composites Environmental Impact

Use

- Composites high strength / weight ratio allows weight reduction
- Part integration facilitates cost & weight reduction
- Increased use lifetime positive impact on environment
- Fuel efficiency in transportation provides positive impact on environment

Resources

- Use of bio-based materials viewed as inherently better
- Nature provides extensive sources of promising fibers
- Extensive research generates interest, challenges w/compatibility & economics
- Synthetic fibers much more widely used

End of Life

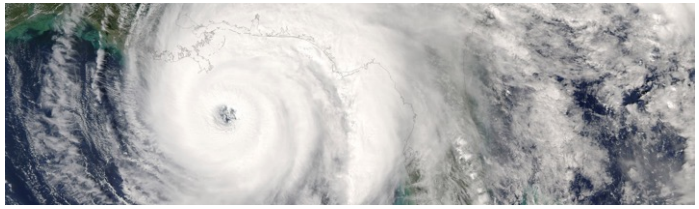
- Grinding & reusing as filler possible but challenges not trivial
- “Un-zipping” cross links & reusing resin impossible

Life Cycle Assessments in Composite Materials

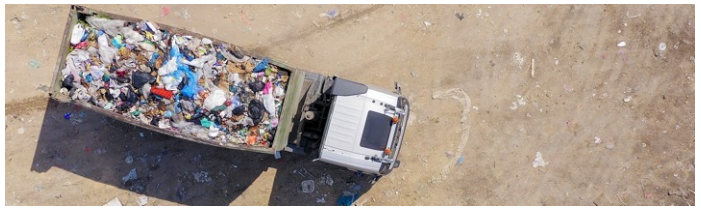
Global Megatrends Influencing Sustainability

Population Growth & Urbanization

Climate Change



Resource Use



Demographics & Social Change

Our Program Areas

GLOBAL CHALLENGES

PLASTIC WASTE	CLIMATE CHANGE	THRIVING SOCIETY

OUR PILLARS

END PLASTIC WASTE IN THE ENVIRONMENT

Collaborative partnerships across the value chain that tackle plastic at source:

- Alliance to End Plastic Waste
- Operation Clean Sweep
- Venture investments

ADVANCE THE CIRCULAR ECONOMY

Technology development and business model innovation:

- Mechanical recycling
- Advanced (molecular) recycling
- Renewable feedstocks

ADDRESS CLIMATE CHANGE

Greenhouse gas emissions reductions from own operations and value chain:

- Carbon reduction program
- Renewable electricity
- Low carbon technology
- Scope 3
- Climate risk

GROW SUSTAINABLE SOLUTIONS

Products and solutions that contribute toward circularity and sustainability:

- *Circulen* polymers: mechanically recycled, advanced (molecular) recycled and renewable-based products

ENHANCE OUR WORKPLACE, OPERATIONS AND COMMUNITIES

Social and environmental issues important for how we operate:

- Safety
- Resource use
- DEI
- Sustainable procurement
- Community investment

Our future focused sustainability goals

ENDING PLASTIC WASTE

2MMT[1]

of recycled and renewable-based polymers will be produced and marketed annually by 2030

FOR EVERY $

we invest in venture funds that address the plastic waste challenge, we help catalyze another 5 dollars from co-investors

ZERO

plastic pellet loss to the environment from our facilities

ADDRESSING CLIMATE CHANGE

NET ZERO

greenhouse gas emissions from operations by 2050[2]

42%

absolute scope 1 and 2 greenhouse gas emissions reduction from operations by 2030[3]

30%

absolute scope 3 greenhouse gas emissions reduction by 2030[3]

50%

minimum of electricity procured from renewable sources by 2030[4]

SUPPORTING A THRIVING SOCIETY

ZERO

incidents, injuries and accidents

ACHIEVE

gender parity in senior leadership globally by 2032

INCREASE

the number of people from underrepresented groups in U.S. senior leadership roles to reflect the general population ratio by 2032

ASSESS

a minimum of 70% of our key suppliers globally using sustainability criteria by 2025

[1] 2 millions metric tons
[2] Our 2050 net zero goal includes scope 1 and 2 emissions
[3] Our 2030 goal includes scope 1 and 2 emissions
[4] Related to 2020 levels

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LyondellBasell Engineering Composites Examples

EC Example #1 – Bio Materials as filler or reinforcement

Bio Reinforcement

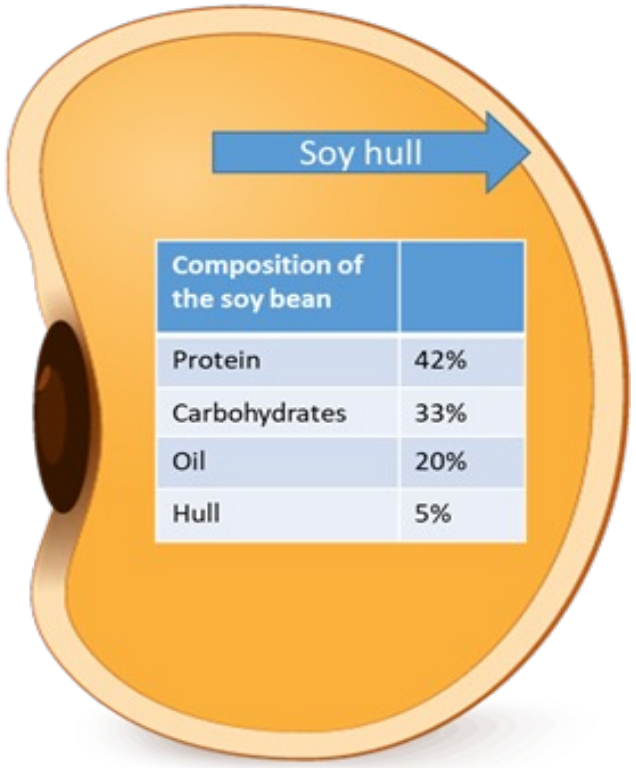
- Flax
- Hemp
- Jute
- Wheat Straw
- **Soy**
- Chicken Feathers
- Switch Grass
- Micro Cellulose

Challenges

- Moisture absorption
- Polymerization inhibition
- Temperature sensitivity

Benefits

- High specific strength & stiffness
- Low carbon footprint



EC Example #2 – Bio source & recycle containing resins

Feedstock

- Vegetable oils
- Lignocellulosic biomass
- Strach rich residue
- Soybean Cake
- Sugarcane bagasse
- Industrial recycle
- Post-consumer recycle

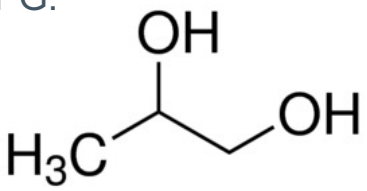
Challenges (to composite compounder)

- Cost
- Availability
- Limited “Green” content in final product

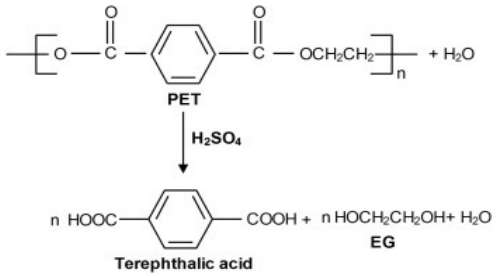
Benefits

- Ease of use
- Low carbon footprint

- **Propylene Glycol – Produced from renewable feedstocks such as soy or corn instead of petroleum.**
  - Identical chemical structure as petroleum-sourced PG;
  - Meets same specifications as petroleum-sourced PG.



- **Terephthalic Acid – Sourced and produced from a post-industrial stream of recycled polyethylene terephthalate.**
  - Purge material from the PET manufacturing process that is created during start-up/shut-down or other process upsets.



EC Example #2 – Bio source & recycle containing resins

Leadership in Energy and Environmental Design (a.k.a. LEED) is the world's most used rating system for the design, construction and operation of high-performance green buildings.

- **Rapidly Renewable Materials category**
  - Reduce the use and depletion of finite raw materials and long-cycle renewable materials.
  - Made from agricultural products harvested within 10-year or shorter cycle.

- **Recycled Content category**
  - Reduce impacts resulting from extraction and processing of virgin materials.

- **LEEDS for every project**
  - Building Design and Construction
  - Interior Design and Construction
  - Building Operations and Maintenance

EC Example #2 – Bio source & recycle containing resins

Net-Molded Shape Test Results

Property	Method	Control SMC	*Premi-Glas* 3501
Tensile Strength (MPa)	ASTM D638	57	75
Tensile Auto Young's Mod (MPa)	ASTM D638	13,000	14,800
Elongation (%)	ASTM D638	0.86	1.03
Flex Strength (MPa)	ASTM D790	140	163
Flex Auto Young's Mod (MPa)	ASTM D790	9,870	10,200
Notched Izod (J/m)	ASTM D256	481	578
Un-notched Izod (J/m)	ASTM D4812	717	923
Arc Resistance (seconds)	ASTM D495	180+	192
Flammability (@ 2.3 mm)	UL 94 V-0	Pass	Pass
Flammability (@ 2.3 mm)	UL 94-5V	Pass	Pass

EC Example #3 – Use of Reclaimed Material

EC Example #3 – Use of Reclaimed Material

EC Example #4 – Recovered Composite Fiber

Recycling Methods

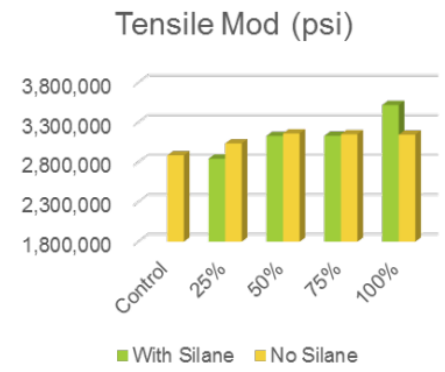
- Mechanical
- Thermal
- Chemical
- High Voltage Fragmentation

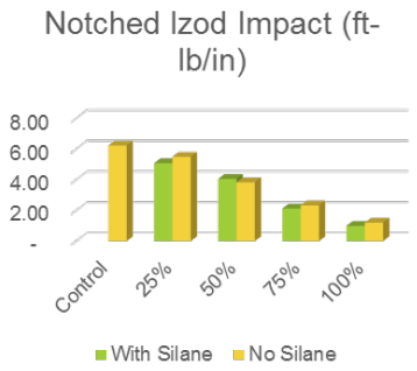
Process and Applications Development for Recycled Mixed-Stream Composites

- PA16-0349-6.29-01
- US Department of Energy
- Establish viability of recycled composite parts using fibers reclaimed through controlled pyrolysis

EC Studied use of Carbon & Glass fibers in BMC

- Strength negatively impacted, minimized w/use of compatibilizer
- Stiffness little if any loss
- Encouraging results for core applications





EC Example #5 – Stacking Technologies

"Stacking" Scenarios/Options

- **Bio Reinforcement/Filler + Bio Resin**
- Bio Resin + Reclaimed Material
- Recycled Fiber + Recycle Containing Resin
- Recycled Fiber + Reclaimed Material

Challenges

- Mechanical properties
- Cost
- Interactions & impact on processability

Benefits

- Strength negatively impacted, minimized w/use of compatibilizer
- Stiffness little if any loss
- Carbon footprint

Property (units)	Method	**Control Average**	Control Stdev	**Exp. Average**	Exp. Stdev
Tensile Strength (MPa)	ASTM D638	**84.5**	10.7	**58.7**	8.82
Flexural Strength (MPa)	ASTM D790	**170**	31.7	**144**	12.3
Flex Mod (MPa)	ASTM D790	**9080**	927	**7480**	792
Izod (J/m)	ASTM D256	**527.7**	1.42	**528.6**	0.74
Notched Izod (J/m)	ASTM D4812	**527.4**	1.45	**527.4**	1.11

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