DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

All-Polyester Multilayer Plastics ('All-Polyester MLPs'): A Redesign for Inherently Recyclable Plastics

2/14/2023
AMO 12

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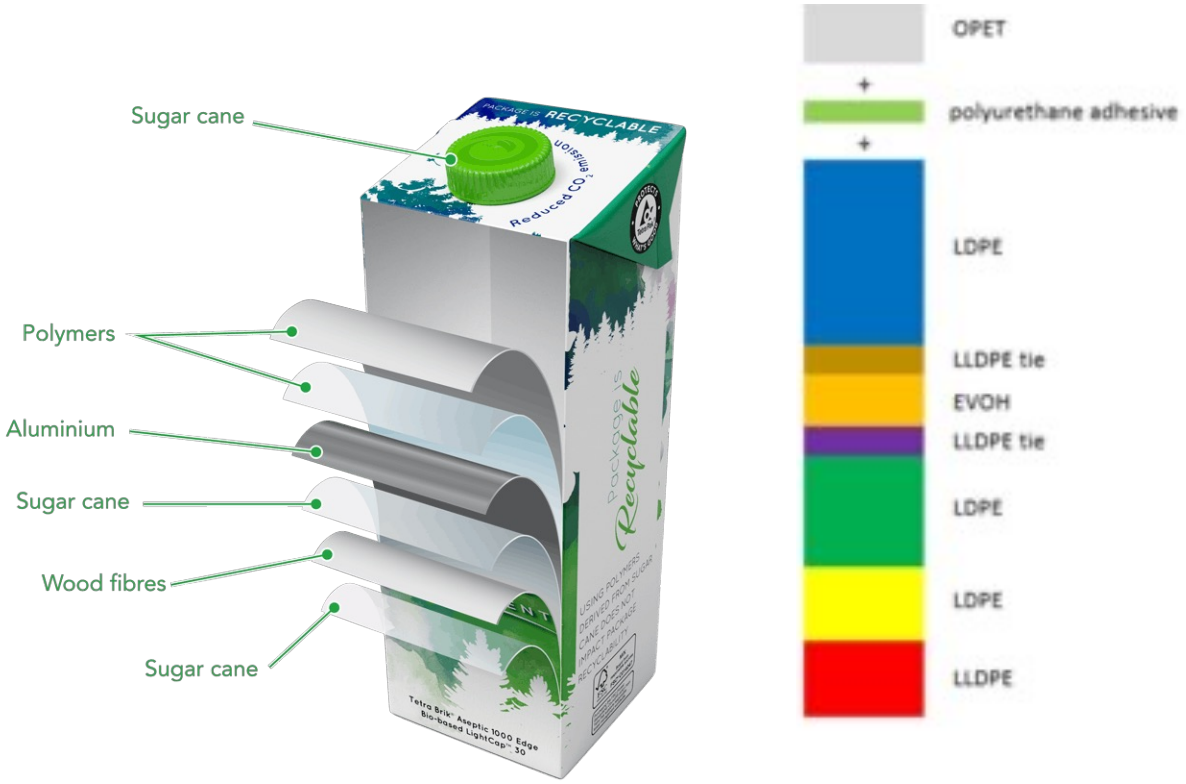
1 - Project Overview

Project Overview- Background

- ~30% of all plastics used in packaging today are multilayer (5-12 layers). For example, meet, beef, pork, fish, nuts, cheese, etc, are all packaged in multilayer.
- Every layer in a multilayer structures serves one or more critical functions.

Project Overview- Challenge

- Multilayers are inherently non-recyclable even post-industrial waste.
- Both chemical and mechanical recycling are not viable for the existing multilayer structures.



Project Overview- Project Goals

Our goal

The overarching goals of this project include:

- To produce 'all-polyester MLPs' that offer packaging performance (e.g., sealing, barrier, mechanical, etc.) that matches or exceeds those of commercial 5-12 layers MLPs.

- Provide multiple EoL solutions (e.g., chemical and mechanical recycling) for 'all-polyester MLPs'.

‘Why all-polyesters’ and not Polyolefins

All-polyesters

- Chemical and mechanically recyclable
- Excellent aroma and flavor retention, excellent printing and excellent mechanical preparties.
- Excellent thermal properties 100^{o}C above than the PE suitable for hot-fill and sterilization
- When making multilayer, No need for tie layers

Polyolefins

- Mechanically recyclable
- Weaker packaging relevant properties such as aroma and flavor retention, excellent printing and excellent mechanical properties.
- Polyolefins has limited use in hot fills etc.
- Need for tie layers

Project Success Criteria

Performance Criteria for 'All-Polyester MLPs'		
Properties	**'All-polyester MLPs' (Target metrics)**	**ASTM Method**
MVTR (38 °C & 90% RH)	0.5-1.5 g/m^2.24h	F-1249
OTR (23 °C & 50% RH)	1-3 cc/m^2.24h	D-3985
Tensile strength at break	30-50 MPa	D-882
Elongation at break	30-500%	D-882
Thickness	40-100 µm	D6988
Toughness	100-150 J/m^2	D256
Elmendorf Tear	546 g	D-1922
Slow Puncture	1000 g	D-7192
Seal Strength	20-100 N/mm	F88 / F88M

End of Life Solutions Success Criteria	
Type of Recycling	**Success Metrics for the 'all-polyester MLPs'**
Mechanically recycled 'all-polyester MLPs'	Tensile strength (20-100 MPa), elongation (120-400%), oxygen permeability (300 cc/m^2. 24h), water vapor (1.0 g/m^2.day)
Chemically recycled 'all-polyester MLPs'	1) >97%% depolymerization in < 60 min at 170 °C or below. 2) Quantitative catalyst recovery and reuse of the same catalyst multiple times.

2 - Project Updates

Project goals alignment with BETO Goals

- This project targets the enormous 100 million tons/year of MLPs that are produced today. ***If this technology captures 20% of the current MLP market (44 billion pounds/year), this will generate a revenue of $44 billion/year.***
- ***S***uppling **3.3 billion lbs/year** of material for packaging manufacturing;
- conserving **>15.8 billion MJ/year** of energy;
- saving **>3.3 billion lbs/year** of feedstock chemicals, which otherwise would not be used for the generation of virgin materials for PET films.
- **2.6 billion lbs/year** of CO_2 year that is currently generated by virgin resin synthesis will be eliminated.

Project goals alignment with BETO Goals (Contd.)

Table: Topic Area Metrics			
Metric	*Unit*	*Minimum Target*	*Stretch Target*
Product Performance	Material properties meet or exceed characteristics required for application	**Meets Characteristics** (Meets Characteristic)	**Exceeds Characteristics** (Exceeds Characteristics)
Economically incentivized	Cost of polymer and/or use of technology compared to multilayer film use for application	**25% Cost improvement** (cost parity)	**50% Cost improvement** (20% Cost improvement)
Carbon utilization	wt% carbon recycled in the final product	**70%** (50%)	**100%** (100%)
Energy savings using recycled film vs. virgin feedstocks	% Energy savings relative to baseline	**60%** (50%)	**70%** (60%)

Note: In the table above, values in **Bold** denote target metrics set by our project team, and the values underlined are those targets required per DOE FOA. Carbon utilization in mechanical recycling is ~100%, while in chemical recycling the carbon utilization is 70% (assuming that 30% is lost during the recovery). Energy saving and CO_2 emissions are calculated based on the REMADE DOE Institute chart.

Team

All-Polyester Multilayer Plastics (‘All-Polyester MLPs’): A Redesign for Inherently Recyclable Plastics

Project Team:

- Dr. Muhammad Rabnawaz (PI)- Michigan State University (MSU)
- Dr. Laurent Matuana - Michigan State University (MSU)
- Dr. Rafael Auras - Michigan State University (MSU)
- Dr. Shiwang Cheng - Michigan State University (MSU)
- Dr. Huan Lei - Michigan State University (MSU)
- Dr. Kevin Simmons - Pacific Northwest National Laboratory (PNNL)
- Ms. Leslie Snowden-Swan - Pacific Northwest National Laboratory (PNNL)
- Mr. Kevin Nelson (Amcor)
- Dr. Abdelwahab (MSU)

MICHIGAN STATE UNIVERSITY

Pacific Northwest NATIONAL LABORATORY

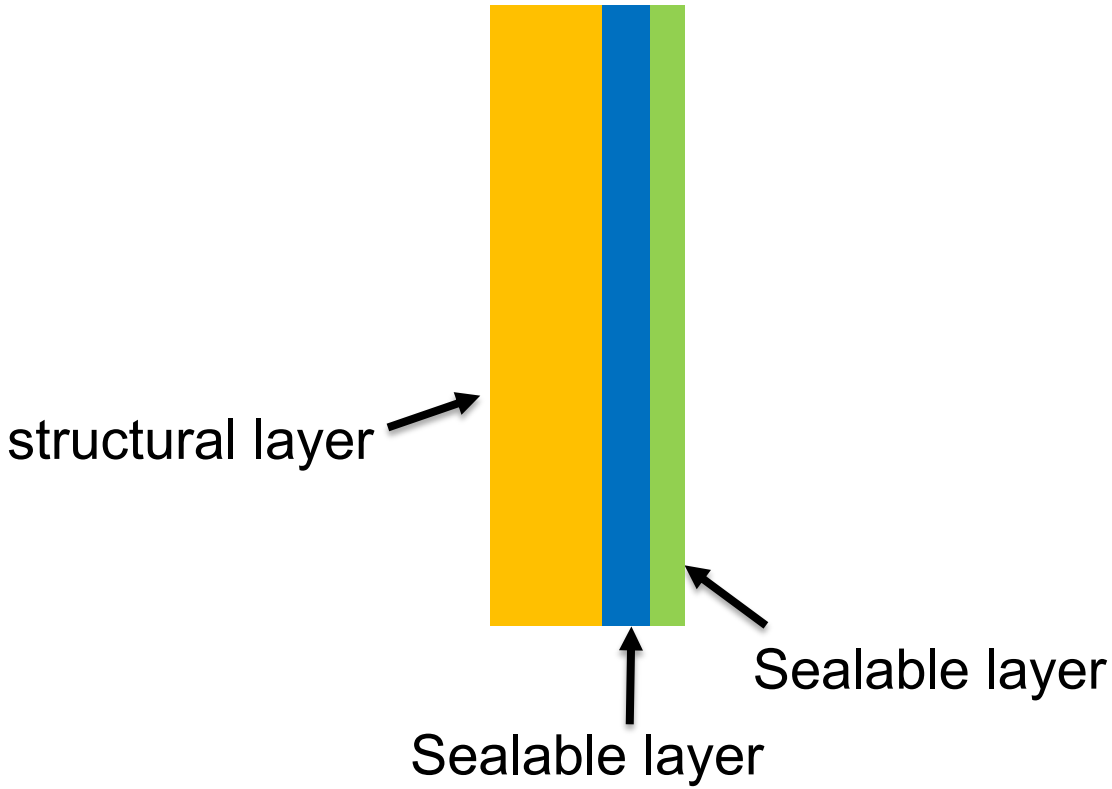
amcor

Specific question our research answers?

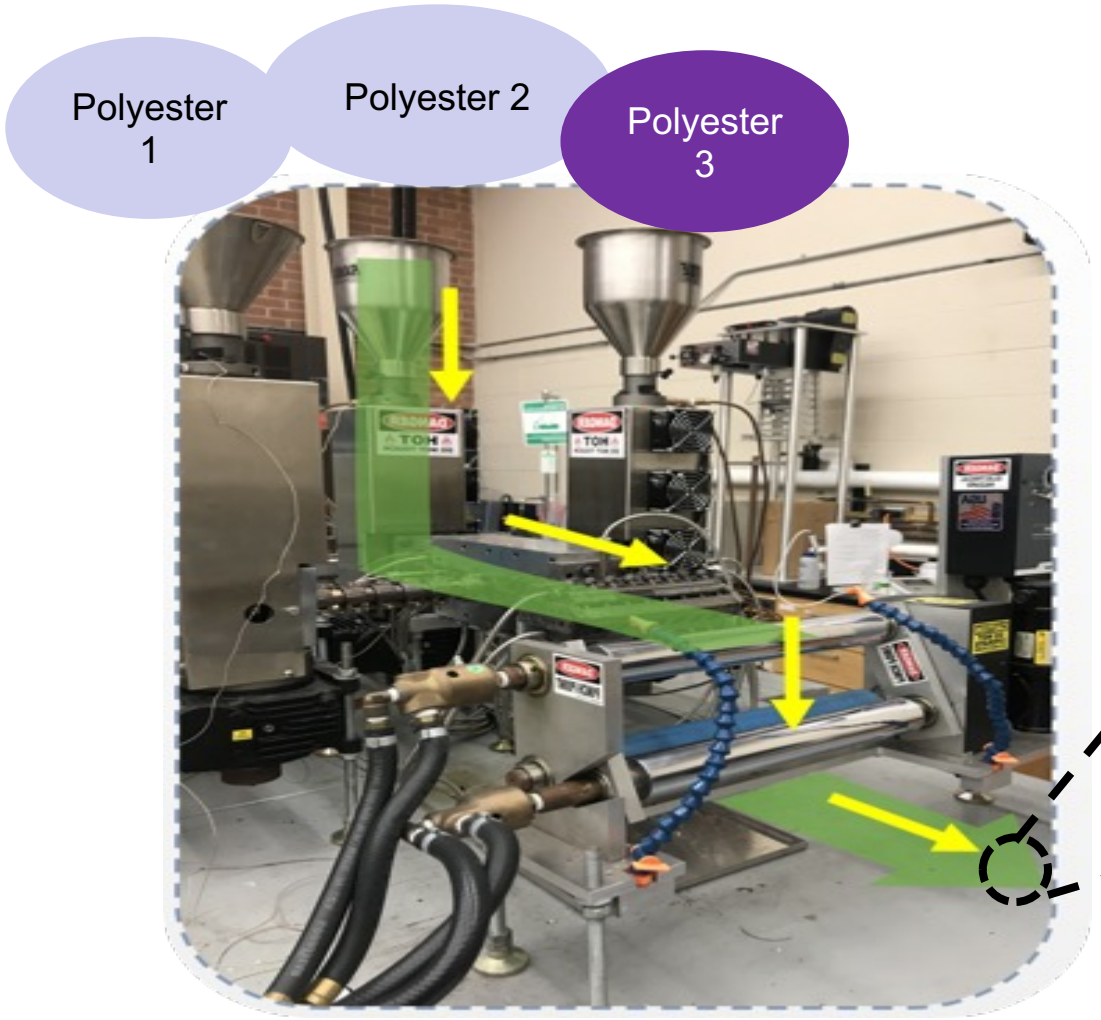
- Validate that ‘all-polyesters’ offer performance matching or exceeding those of non-recyclable multilayers (the success criteria is shown on above)
- Validate the economics of ‘all-polyesters’ against non-recyclable multilayers
- Validate end of life scenarios (chemical and mechanical recycling)

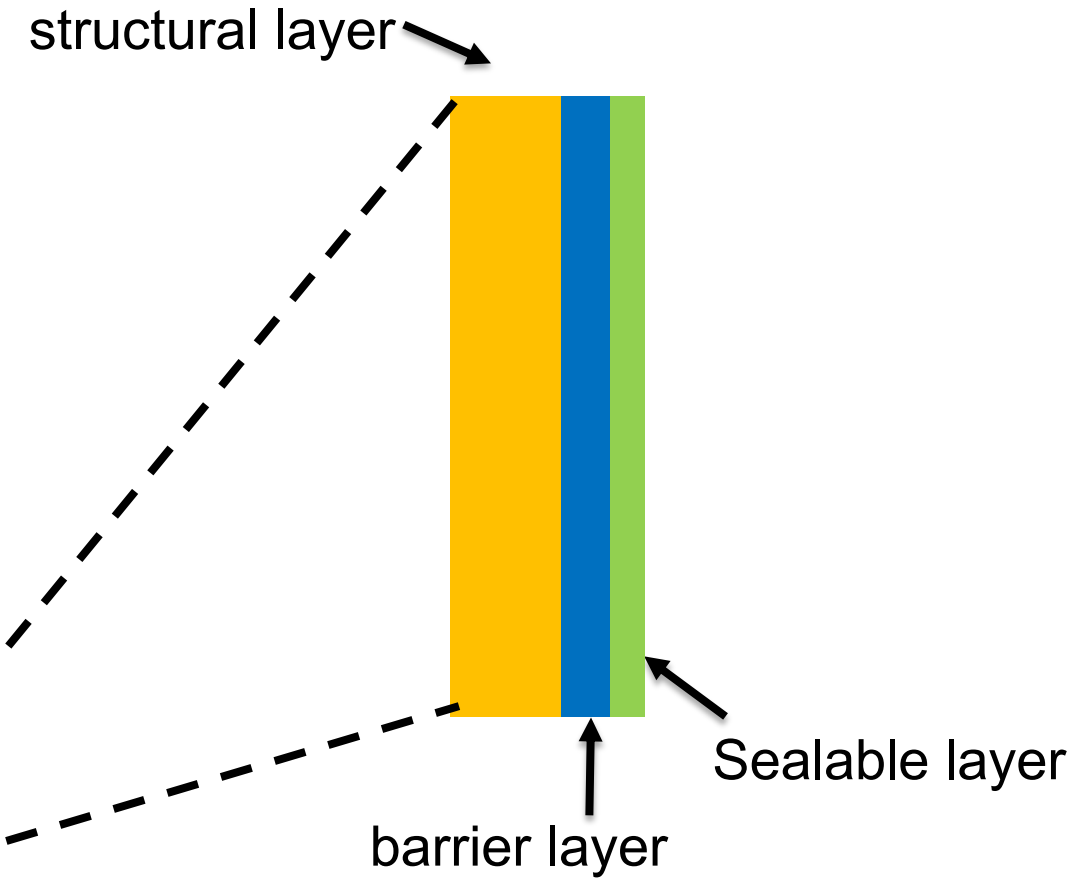
Approach for making all-polyester multilayer

Targets: Create ‘all-polyesters multilayer structures meeting success criteria



Making of all-polyester multilayer





Performance analysis

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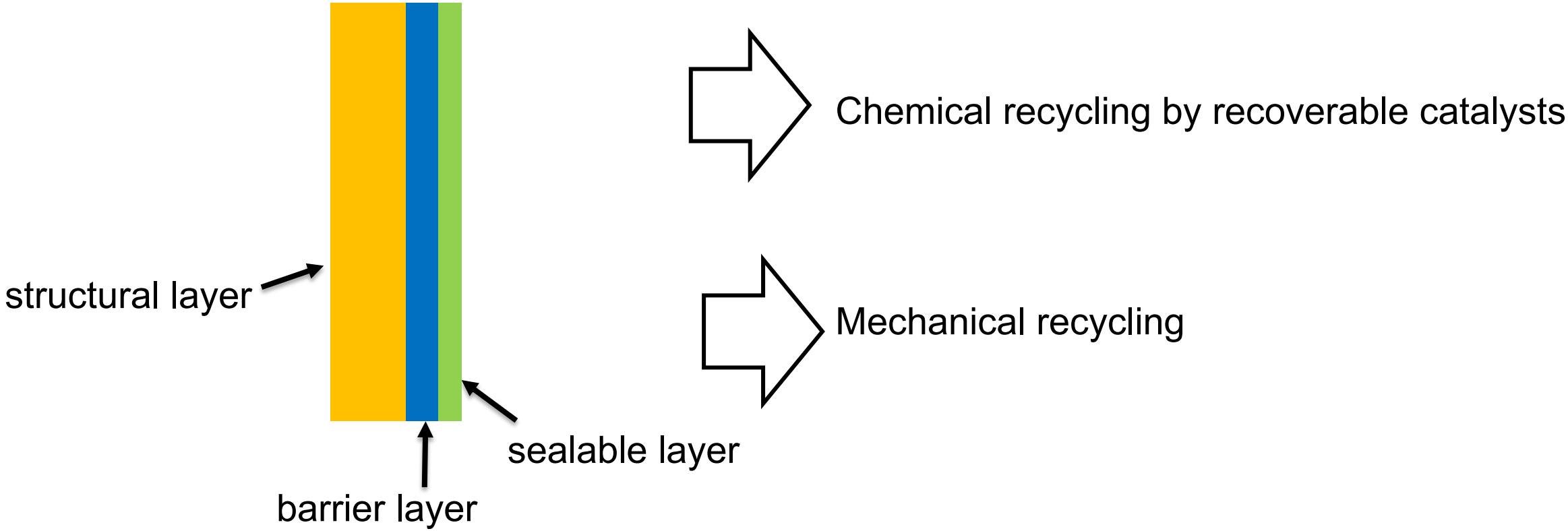
End of life of all-polyesters



Success criteria for end of life

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Challenges

- None as of now.

GO/NO GO DECISIONS

Milestone Type (Milestone or Go/No-Go Decision Point)	Milestone Number* (Go/No-Go Decision Point Number)	Milestone Description (Go/No-Go Decision Criteria)	Milestone Verification Process (What, How, Who, Where)	Anticipated Date (Months from Start of the Project)
Go/No-Go Decision Point	**G1**	Successful production of an all polyester MLP either through lamination or co-extrusion with properties matching or exceeding those listed in Table 1 will be a GO decision.	ASTM protocols for properties assessment (MSU)	18

Success Criteria for GO/NO GO

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Diversity, equity, and inclusion in your project plan

Diversity, equity, and inclusion in your project plan

Diversity, Equity, and Inclusion Plan (DEIP)			Status
Diversity, Equity, and Inclusion Plan (DEIP)	Milestone	Recruit, train, and mentor at **NINE** Underrepresented minority undergraduate students on this project	4 URM students are already mentored on this project
Diversity, Equity, and Inclusion Plan (DEIP)	Milestone	Reach out to >200 middle- and high-school students with a focus on URM undergraduate students/year. At least 12 students inspired to spend a day on campus and visit our laboratory facility and at least 50% of these invited students willing to pursue STEM disciplines for their UG studies based on survey feedback.	Multiple outreach activities are in pipeline

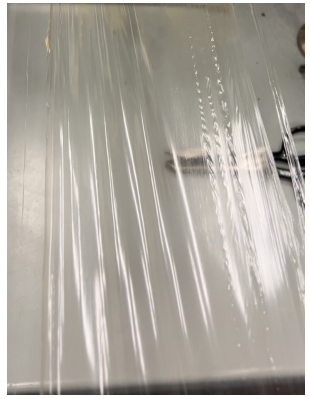
3 - Progress and Outcomes

Progress and Outcomes

Milestones	Month	% completed	comment
Project verification	M3	100%	successful
Design and select four all-polyesters multilayer	M6	100%	successful
Making of four all-polyesters multilayer by lamination	M9	50%	On-Track

We are in the month 8 of this project.

Barrier performance of multilayer



Polyester 1

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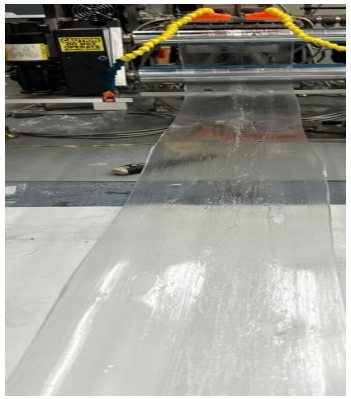

Polyester 2

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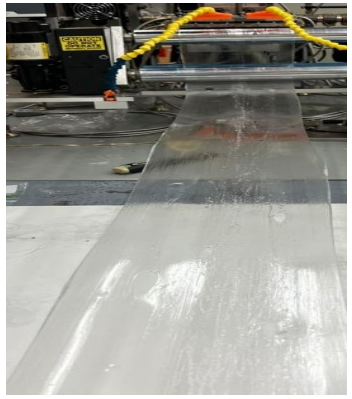
Polyester 3

Properties	'All-polyester MLPs' (Target metrics)	All-polyester multilayer 1 (without nanofiller and unstreched)	ASTM Method
WVTR (38 °C & 90% RH)	[0.05-0.15 g.mm/m^2.24h]	1.00 ± 0.003	F-1249
OTR (23 °C & 50% RH)	[0.1-0.3 cc.mm/m^2.24h]	1.88 ± 0.70	D-3985

Barrier performance of multilayer

Polyester 1

+



Polyester 2

+

Polyester 3

Multilayer film with nanoclay

Properties	'All-polyester MLPs' (Target metrics)	All-polyester multilayer 2 (with nanofiller and unstreched)	ASTM Method
WVTR (38 °C & 90% RH)	[0.05-0.15 g.mm/m^2.24h]	1.56 ± 0.09	F-1249
OTR (23 °C & 50% RH)	[0.1-0.3 cc.mm/m^2.24h]	1.34 ± 0.04	D-3985

Summarize the status of key milestones

- Project is on-track for its four all-polyesters multilayer structures

- D*iversity, equity, and inclusion (5 undergrads are sponsored on this project, who got cross-disciplinary trainings. Four of these were female students.*

4 - Impact

Impact your project on the state of technology and/or the industry if successful

- Offer US manufactures to find recyclable alternative to the existing non-recyclable.

- Enable US manufacturers to sell their packaging worldwide as this technology is in compliance with global regulations.

Summary

- *'All-polyester MLPs' has the potential to offer fully recyclable alternatives to the existing non-recyclable*
- *Validation of the performance of All-polyesters MLPs' against commercial non-recyclable is under progress*
- *The project will strengthen US manufacturers position on global-stage in the packaging*

Quad Chart Overview

Timeline

- *July 01, 2022*
- *June 30, 2025*

	FY22 Costed	Total Award
DOE Funding	*(10/01/2021 – 9/30/2022)* *$21,436.26*	*(negotiated total federal share)* *$4,092*
Project Cost Share *		

TRL at Project Start: 2
TRL at Project End: 4

*Only fill out if applicable.

Project Goal

Develop all-polyesters as recyclable multilayer as alternative for the existing non-recyclable multilayer

End of Project Milestone

i) Create 'all-polyester MLPs' that offer packaging performance that matches or exceeds those of commercial 5-12 layers MLPs. Establish chemical and mechanical recycling as EoL solutions for 'all-polyester MLPs' such as protocols for the mechanical recycling of 'all-polyester MLPs' and TEA/LCA component of that indicates feasibility to meet carbon, energy, and cost targets from the FOA.

Funding Mechanism

FOA#DE-FOA-0002473

Topic Area 2. Redesign of Multilayer Films for Infinite Recyclability or Biodegradability

Project Partners*

- MSU
- PNNL
- Amcor

Additional Slides

(Not a template slide – for information purposes only)

- *The following slides are to be included in your submission for evaluation purposes, but will **not** be part of your oral presentation –*
- *You may refer to them during the Q&A period if they are helpful to you in explaining certain points.*

Responses to Previous Reviewers' Comments

- If your project has been peer reviewed previously, address 1-3 significant questions/criticisms from the previous reviewers' comments which you have since addressed
- Also provide highlights from any Go/No-Go Reviews

Note: This slide is for the use of the Peer Reviewers only – it is not to be presented as part of your oral presentation. These Additional Slides will be included in the copy of your presentation that will be made available to the Reviewers.

Publications, Patents, Presentations, Awards, and Commercialization

- List any publications, patents, awards, and presentations that have resulted from work on this project
- Use at least 12 point font
- Describe the status of any technology transfer or commercialization efforts

Note: This slide is for the use of the Peer Reviewers only – it is not to be presented as part of your oral presentation. These Additional Slides will be included in the copy of your presentation that will be made available to the Reviewers.