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Building sustainable barrier solutions

Sustainable possibilities through Kuraray's high-barrier EVAL™ EVOH

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Kuraray America, Inc.
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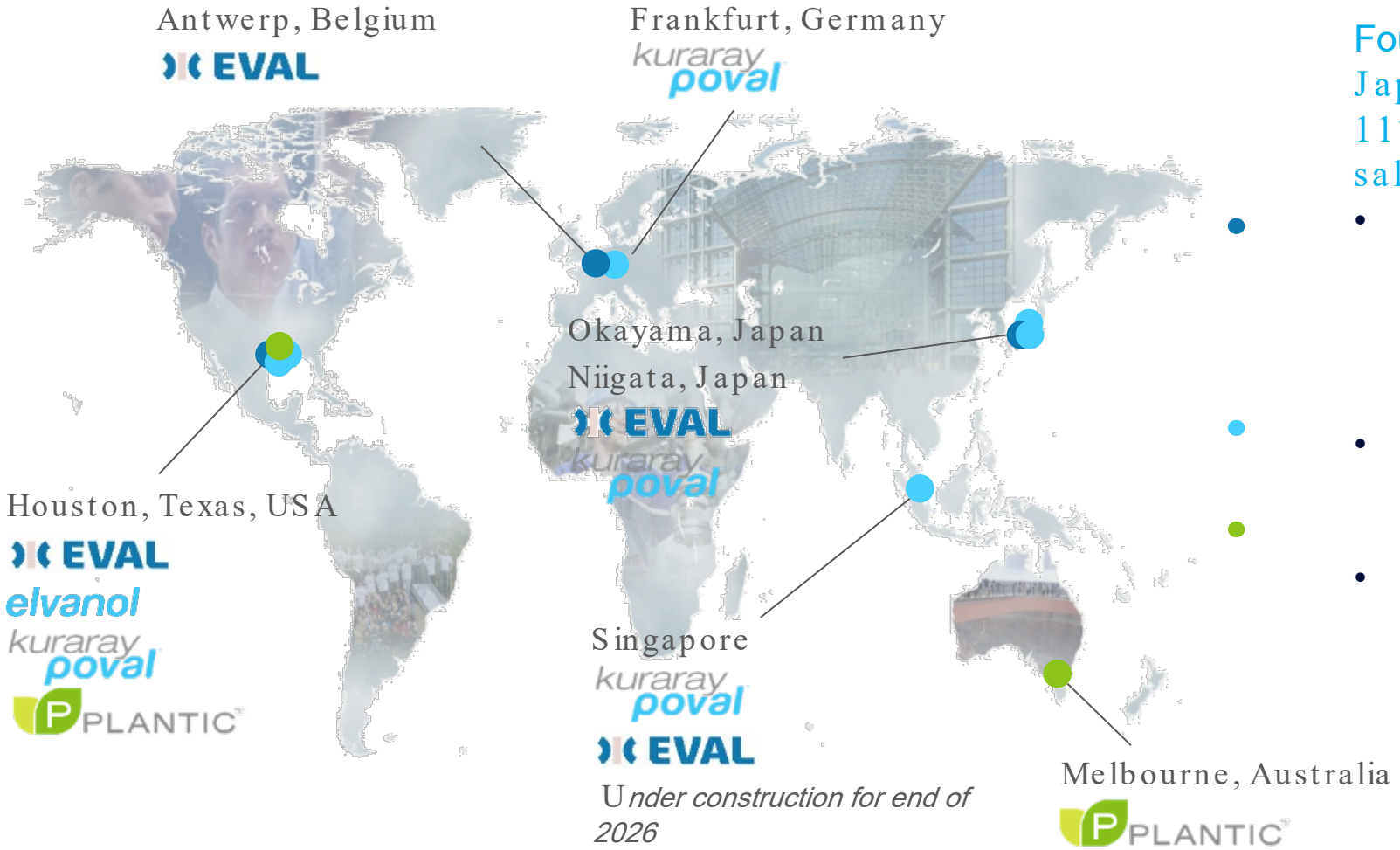
EXPERTISE | ACTION

For people and the planet, pioneering sustainable packaging solutions that improves the environment and enhances the quality of life throughout the world

Outline

1. EVAL EVOH …the recyclable barrier of choice
2. Extended food shelf-life with minimal packaging
3. Beyond the package, adding value upstream in the food supply chain and protecting the environment
4. Plantic™, the starch-based barrier solution

Kuraray is a world leader in performance-based polymer and specialty materials technologies

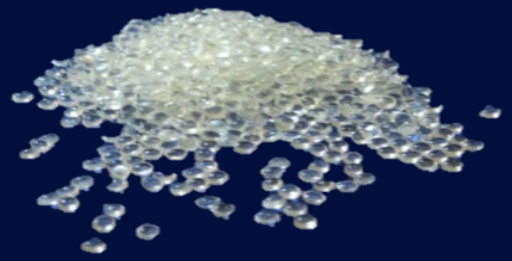


Founded in 1926, headquartered in Japan, operating in 31 countries, with 11700 employees and $5.2 billion net sales

- World's largest EVOH gas barrier resin producer
  - Significant capacity increase for 2026
- World's largest PVOH water soluble polymer producer
- PLANTIC™ natural barrier polymer
  - Global leader in thermoplastic starch gas barrier

EVAL™ ethylene vinyl alcohol (EVOH) resin

The market proven benchmark for high barrier extended shelf-life food packaging



- A semi-crystalline ethylene copolymer
- Enables high barrier multilayer coextrusion
- Commonly recyclable in existing infrastructure

EXCEVAL™ hydrophobic modified polyvinyl alcohol (PVOH)

A versatile high gas barrier water-soluble polymer common to the paper industry

- Solution coating
- Wash-away recyclable, repulpable, biodegradable

PLANTIC™ thermoplastic starch barrier

A performance-based natural polymer that is challenging traditional barrier packaging

- Extrusion coating, cast or film lamination
- Biobased, wash-away, recyclable, repulpable, biodegradable, compostable

For oxygen barrier, EVOH is in a class of its own

Material	Oxygen Permeability (20ºC, 65%RH)	Water Vapor Permeability (38ºC, 90%RH)
	cc.20 µm/m ^{2}.day.atm	g.30 µm/m ^{2}.day
EVAL™ L171B (27 mol% Et.)	**0.1**	63
EVAL™ F171B (32 mol% Et.)	**0.3**	45
EVAL™ H171B (38 mol% Et.)	**0.7**	32
EVAL™ E171B (44 mol% Et.)	**1.9**	28
EVAL™ G176B (48 mol% Et.)	**3.7**	20
PA6	45	220
PET	150	13
HDPE	2300	**6.2**
PP	3000	**11**
LDPE	10000	**19**

Polyolefins complement EVOH with good water vapor barrier and heat sealability

EVOH has emerged as the recyclable barrier of choice

Optimizing monomaterial packaging design

Monomaterial or Designed for Recycling structures imply replacing materials that can't or are difficult to recycle:

- ⦸ Aluminum foil – clogs filter screens
- ⦸ PVDC – releases HCl

CEFLEX
A CIRCULAR ECONOMY FOR FLEXIBLE PACKAGING

Monomaterial packaging:
>90% PE or >90% PP

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CEFLEX (June 2020), Designing for a circular economy, Technical Report, Phase 1

Plastics recycling value chain

Association of Plastics Recyclers (APR)

- APR is the recognized recycling authority in the U.S.
- It establishes design guides and technical protocols for deeming packaging technically recyclable
- A package is recyclable if
- 1) >60% of the community has access to collection,
- 2) it can be properly sorted in a MRF,
- 3) it can be reprocessed for use into another product

American Society for Testing and Materials (ASTM)

- Established the resin identification codes (RIC)

Sustainable Packaging Coalition (SPC)

- Develops the How to Recycle (H2R) labels for packaging
- Refers to the APR for technical guidance

The Recycling Partnership

- Mobilizes funds and facilitates grants for local communities to modernize MRFs, improve access to resources, and provide curbside recycling carts to households across the nation

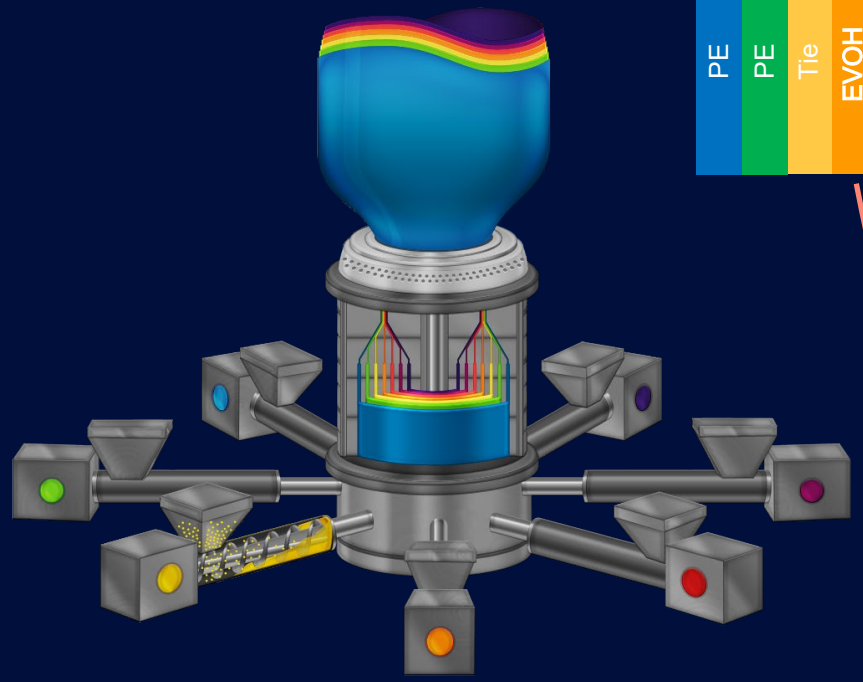
Circular Action Alliance (CAA)

- The only recognized Producer Responsibility Organization (PRO) in various states in the U.S.
- Members: Amazon, Clorox, CocaCola, Colgate, Danone, General Mills, Keurig, KraftHeinz, Mars, Mondelez, Nestle, Pepsico, P&G, SC Johnson, Target, Unilever, Walmart
- Five states (CA, OR, CO, ME, MN) will begin collecting fees in 2026-2027, and nine more have proposed bills

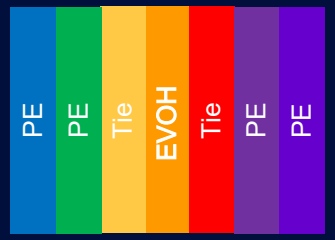
Recycling guidelines in the US/Canada

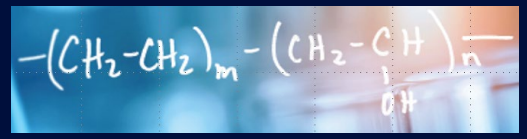
Segment	APR Design Guidance					Critical Guidance Recognitions
	Barrier Solution					
	EVOH	PA	SiOx , AlOx	Metalized coatings	PVDC, Aluminum Foil	
PE Flexible	Testing Required	Testing Required	Preferred	Testing Required	Not recyclable	• Multiple material suppliers • Constantia 5% EVOH • IsoFlex 8% EVOH, no compatibilizer
PP Flexible	≤ 6% EVOH Preferred	Testing Required	N/A	N/A	N/A	• Now intended for Canada only
HDPE Rigid	≤ 6% EVOH Preferred	Testing Required	N/A	N/A	N/A	• Berry 7.6% EVOH in HDPE tube
PP Rigid	≤ 6% EVOH Preferred	Testing Required	N/A	N/A	N/A	• Silgan 8% EVOH in PP tub/cup • Berry 12% MXd6 in PP tub/cub

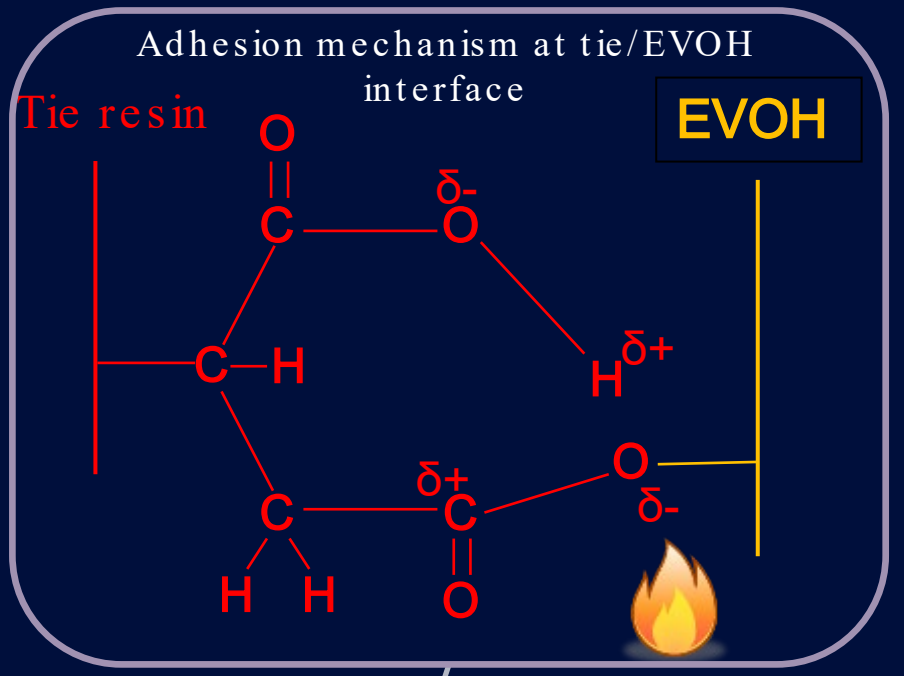
Monomaterial solutions through multilayer coextrusion technology

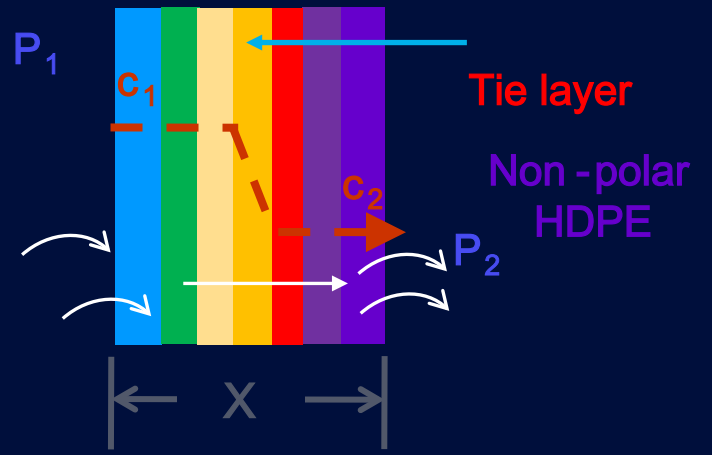


Schematic of a 7-layer blown film die





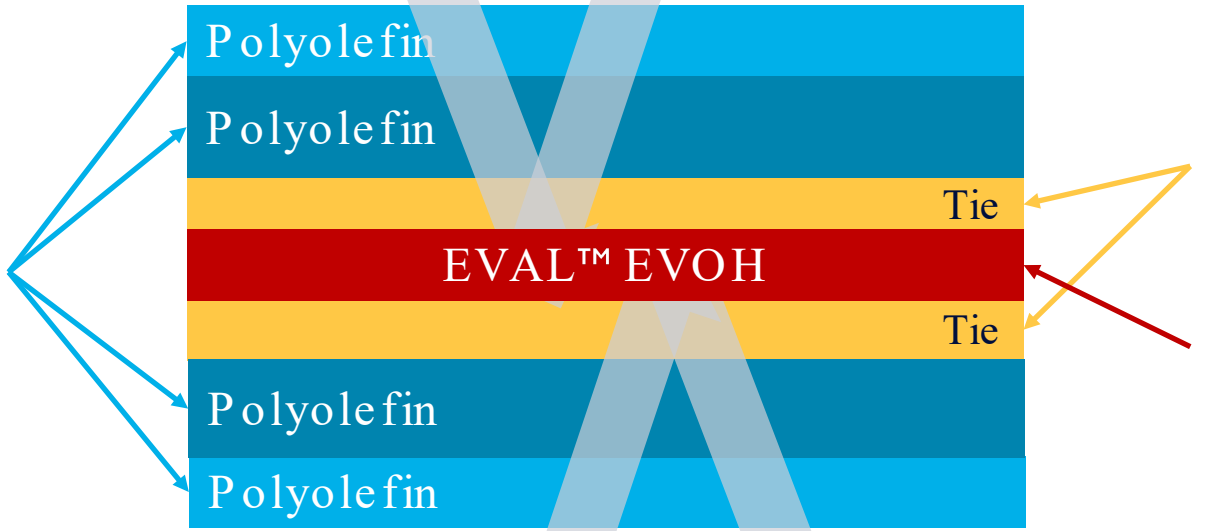




Die illustration courtesy of Viaflex

Preserving food quality

OUTSIDE
Oxygen
Off -odors, off -flavor, contaminants



Polyolefins
- Water vapor barrier
- Abuse resistance
- Heat sealability

Tie layers
- *Physical* adhesion at PO/tie interface
- *Chemical* adhesion at tie/EVOH interface

EVAL EVOH
- Preserves food quality
- Extends shelf life

Flavor, aroma,
MAP gases
INSIDE

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1. Who is Kuraray and what is EVAL™ EVOH?
2. EVOH, the recyclable barrier of choice
3. Extended food shelf-life with minimal packaging

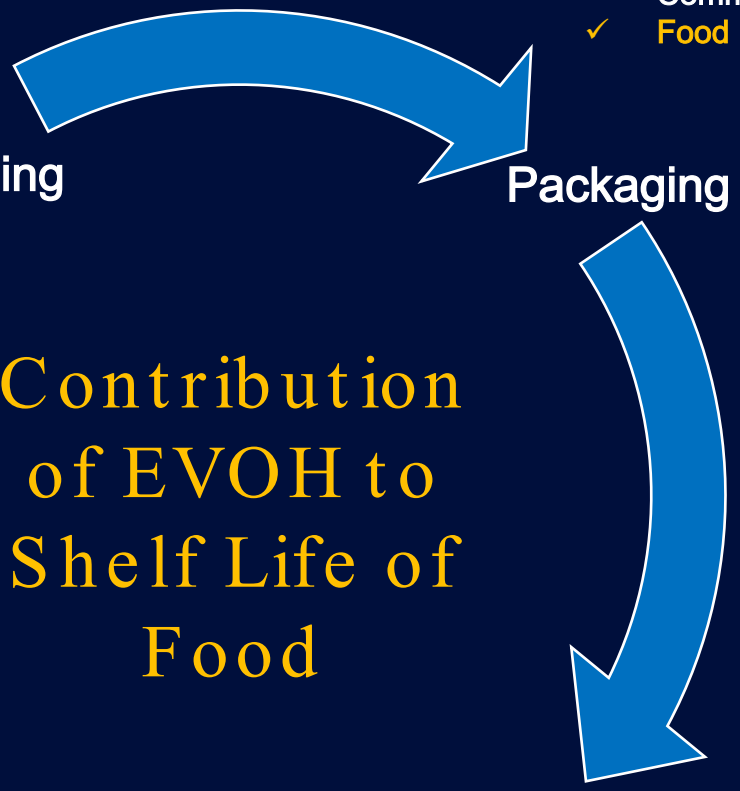
The EVAL™ high-barrier packaging revolution…

A versatile alternative gas barrier to metal and glass

Protecting quality and reducing food waste, in minimal and recyclable packaging

3. Beyond the package, sustainable industrial solutions for the environment

Contribution of EVOH to Shelf Life of Food



Versatile barrier technology
- ✓ MAP, aseptic filling
- ✓ UHT, HPP, hot filled
- ✓ Pasteurization
- ✓ Retort sterilization

Food processing

Packaging

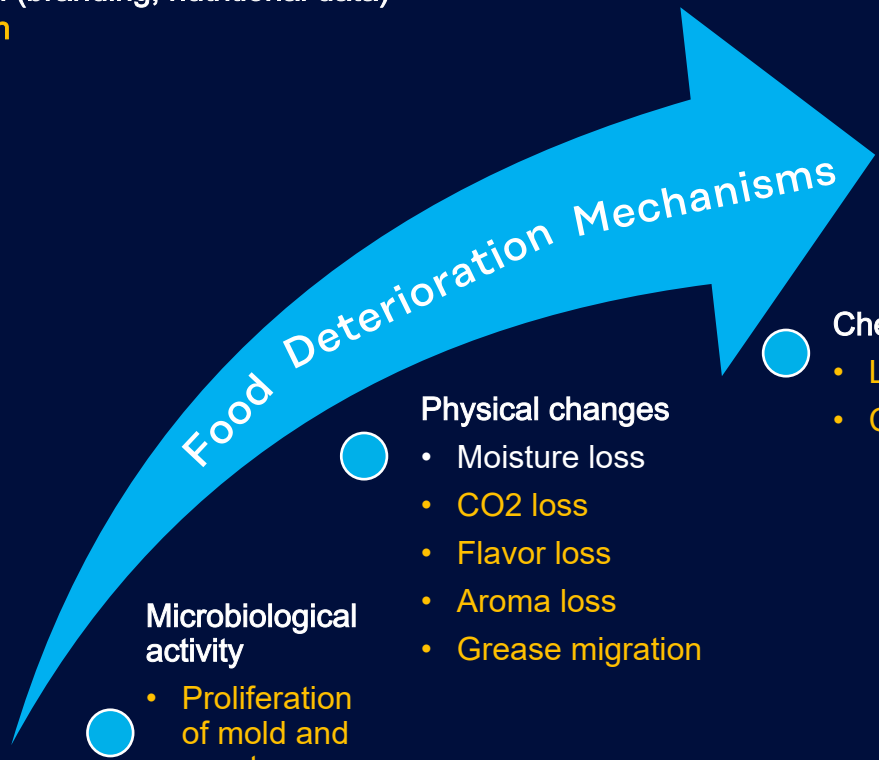
- ✓ Utility (design flexibility, robustness, convenience)
- ✓ Communication (branding, nutritional data)
- ✓ Food Protection

Environment

- ✓ Temperature
- ✓ Relative humidity
- ✓ UV exposure
- ✓ Abuse resistance

Product characteristics

- ✓ pH, water activity
- ✓ Lipids, vitamins
- ✓ Antioxidants, etc.

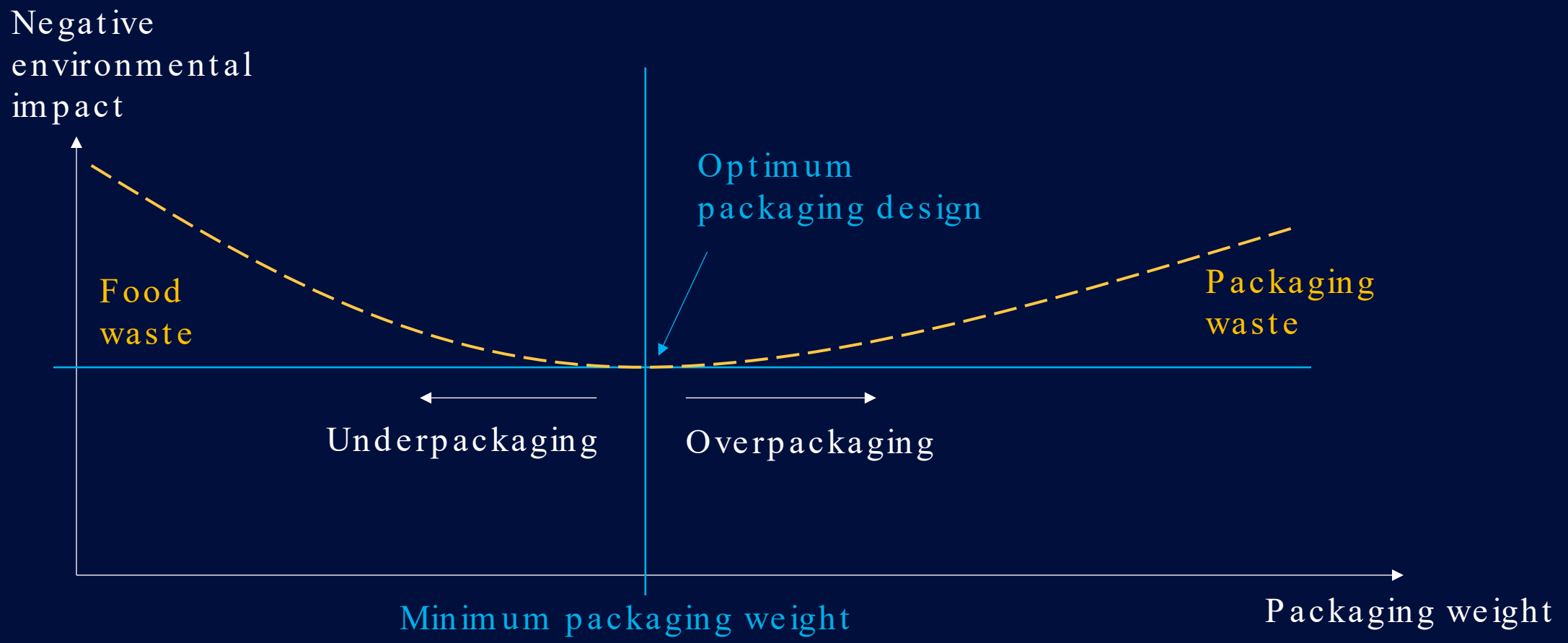


Chemical changes
- Lipid oxidation
- Color change

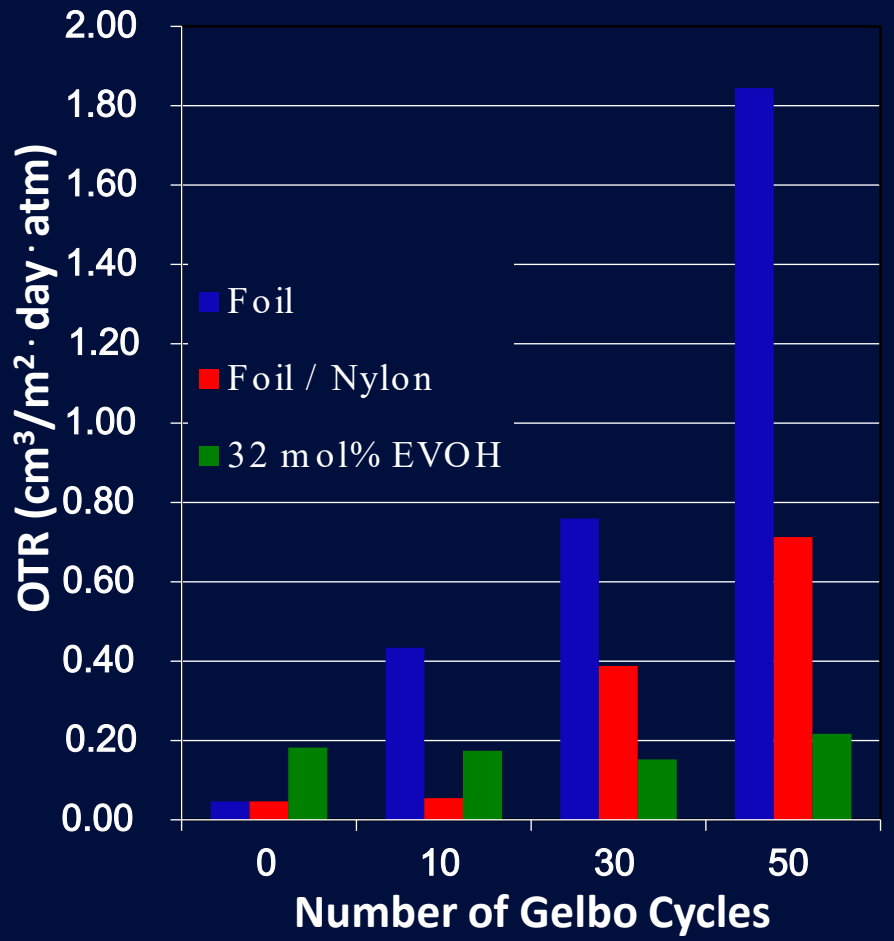
Physical changes
- Moisture loss
- CO2 loss
- Flavor loss
- Aroma loss
- Grease migration

Microbiological activity
- Proliferation of mold and yeasts

Balancing functionality with environmental impact and cost is a key role of packaging engineers



A reliable barrier solution

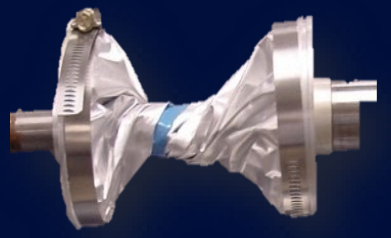


Foil = LDPE / tie / **Foil** / tie / LDPE – (65/12/8/12/38 µm)

Foil / Nylon = BOPA / LDPE / **Foil** / tie / LDPE – (20/12/8/12/100 µm)

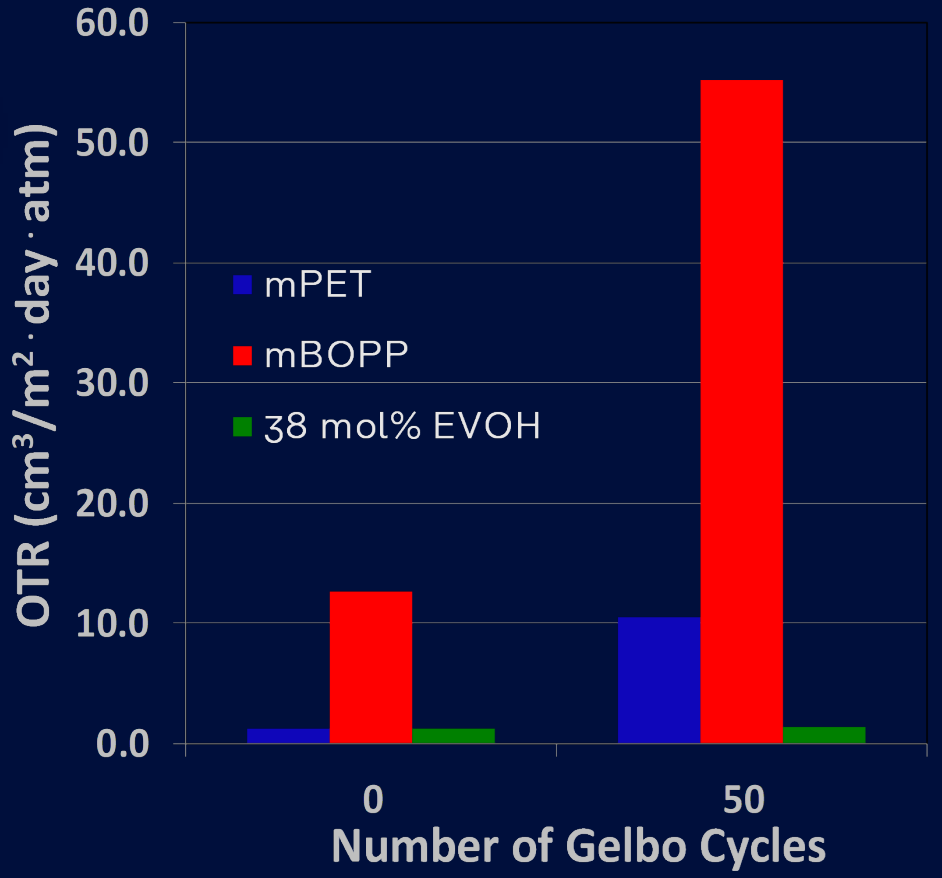
32 mol% EVOH = LDPE / tie / **EVOH** / tie / LDPE - (65/5/12/5/65 µm)

EVAL™ F171B (32 mol% et. EVOH)



Gelbo flex
ASTM F193-92

Oxygen
Transmission
Rate
ASTM D3985



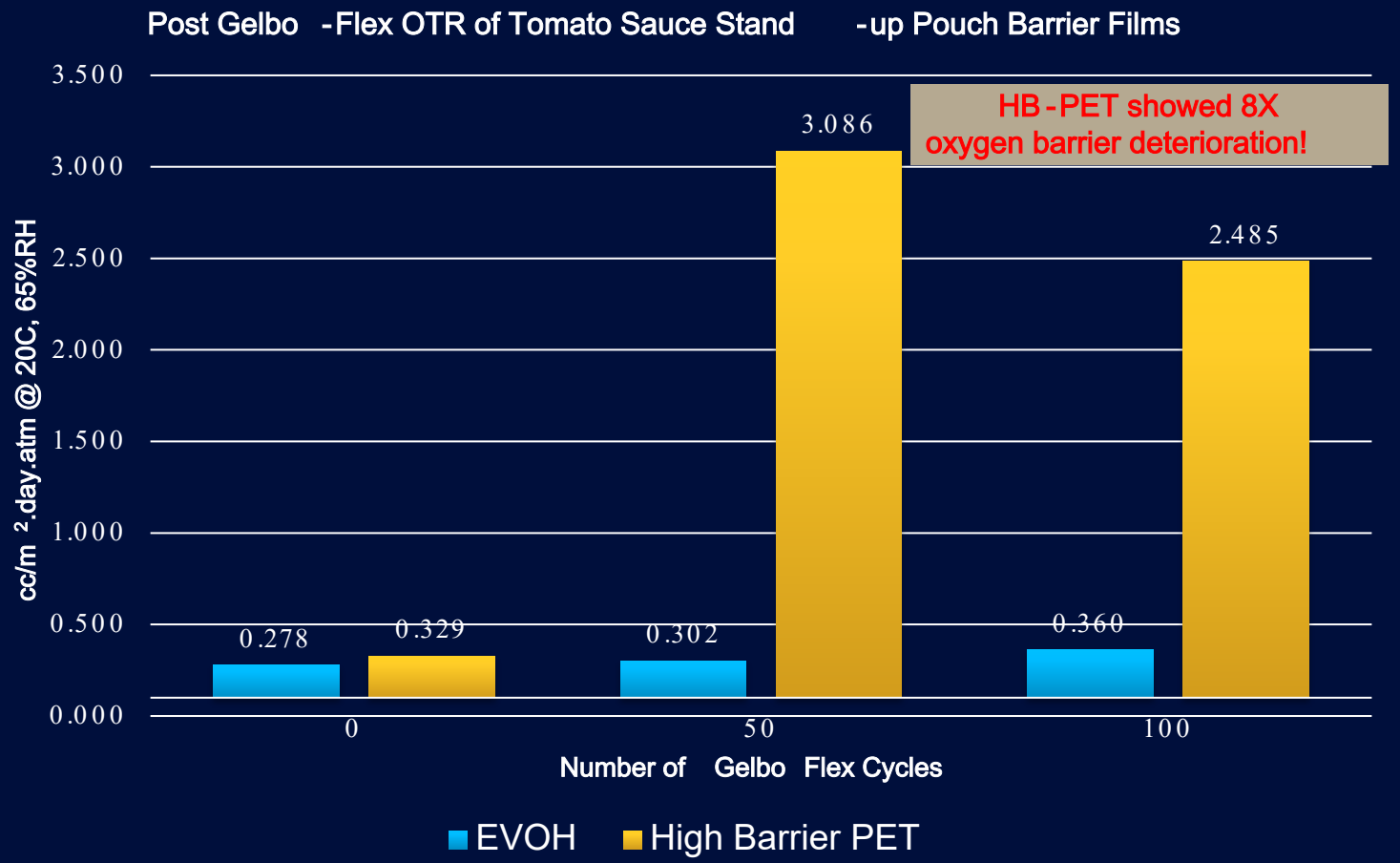
LLDPE//**mOPET**//LLDPE – (22//15//32 mm)

LLDPE//**mBOPP**//LLDPE – (39//18//51 µm)

LLDPE / tie / **EVOH** / tie / LLDPE - (20/7/7/7/39 µm)

EVAL™ H171B (38 mol% et. EVOH)

Tomato puree packaging example



EVOH: {PET14 // mPET14 // [PE/EVOH/PE]74} 115, 5μm 32 mol% et. EVOH

High Barrier PET: {PET15 // mPET12 // PE80} 121

Evolution of tomato sauce packaging

Evolution of the tomato paste pouch

- Light and compact
- Hot filled and shelf stable
- Microwavable

Steel can	Stand up pouch	Stand up pouch	Stand up pouch	*Future*
45 g of packaging	12 g	8 g	7 g	***Monomaterial***
Steel // Epoxy	PET // Al // PE	PET // mPET // PE/tie/ **EVOH** /tie/PE	PET // PET // PE/tie/ **EVOH** /tie/PE	*BOPE// PE/tie/ **EVOH** /tie/PE*
Not microwavable	Not	Not	*Microwaveable*	*Recyclable*
3 year shelf life	1 year	1 year	1 year	

Light and economical

UHT extended shelf-life milk pouch

- 90 days without refrigeration
- Facts vs. aseptic carton
  - 26g to 6g unit package weight reduction
  - 65% package cost reduction
- PE / white PE / tie / EVAL™ / tie / black PE / PE

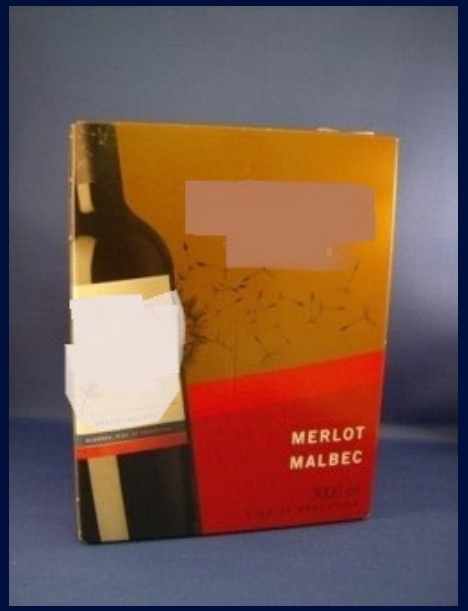
Minimalistic packaging

Water pouch

- Flavor and aroma profile of water is easily affected
- EVOH and the right choice of sealant materials make this possible

3.8 L bottle	*5 L pouch*
HDPE jug + LDPE cap	LDPE / tie / **EVAL ™** / tie / LDPE
65 g + 2 g weight	28 g

Bulk packaging solutions



3L Bag-in-box wine
- ✓ 30-day viable after opening
- ✓ 85% less packaging weight
- ✓ 53% lower CO2 emissions

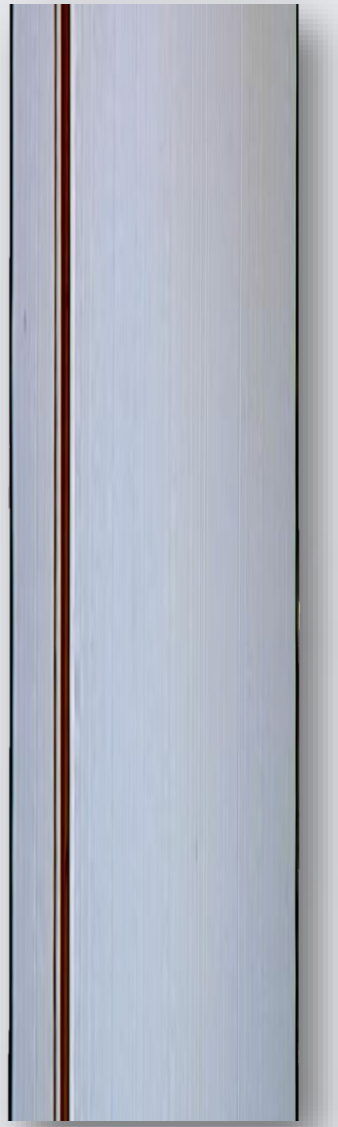
1000L FIBC
(flexible intermediate bulk container)
1 ton vacuum packed almonds

24000L Flexitank
- ✓ Fits in a 20’ container
- ✓ 15% higher payload than 300-gallon IBC
- ✓ 44% higher payload than 50-gallon drums

Clearly delicious

Visible quality in a transparent diced fruit blow-molded jar

- Product visibility for consumer appeal
- Easy-open, reclosable convenience
- Extrusion blow molded jar
- PP / tie / EVAL™ / tie / PP



Safe enough for your baby

Light and convenient baby food thermoformed tub

- Retort sterilized package
- PP / tie / EVAL™ / tie / PP

OR

- Aseptically filled package
- PS / tie / PE / tie / EVAL™ / tie / PE

89 g → 10 g packaging material
56 : 44 → 92 : 8 food : package ratio

BUKOWSKI, Todd and RICHMOND, Michael, "*A Holistic View of the Role of Flexible Packaging in a Sustainable World*," Flexible Packaging Association, 2018, pp 142-145

..as well as safe for your pet!

Wet dog food

- Retort processed, shelf stable
- Cast extruded, thermoformed packaging
- PP / regrind / tie / EVOH / tie / regrind / PP

Outline

1. Who is Kuraray and what is EVAL™ EVOH?
2. Extended food shelf-life with minimal packaging
3. EVOH, the recyclable barrier of choice

Preferred recyclable substitute for PVDC and foil…

HDPE rigid: EVOH up to 6% Full compatibility by APR (US) and RecyClass (EU)

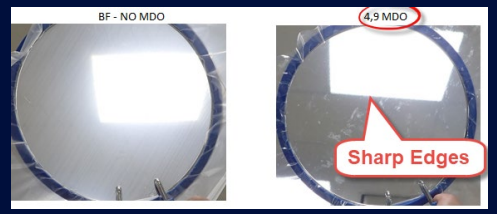
PE flexible: EVOH up to 5% Full to Limited compatibility by CEFLEX (EU) and RecyClass (EU)

4. Beyond the package, sustainable industrial solutions for the environment

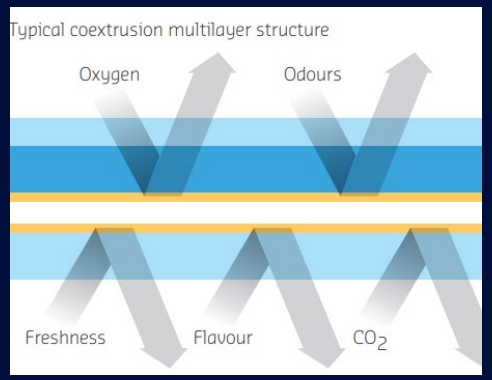
Benefits of Machine Direction Orientation

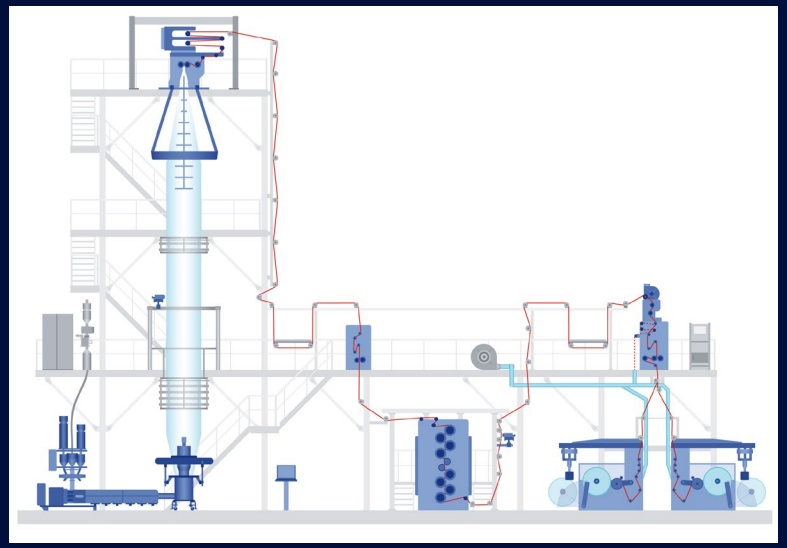
- Mechanical properties improvement:
  - Stiffness
  - Tensile strength
  - Tear (Elmendorf TD 30%up)

- Optical improvement:
  - Clarity
  - Haze
  - Gloss

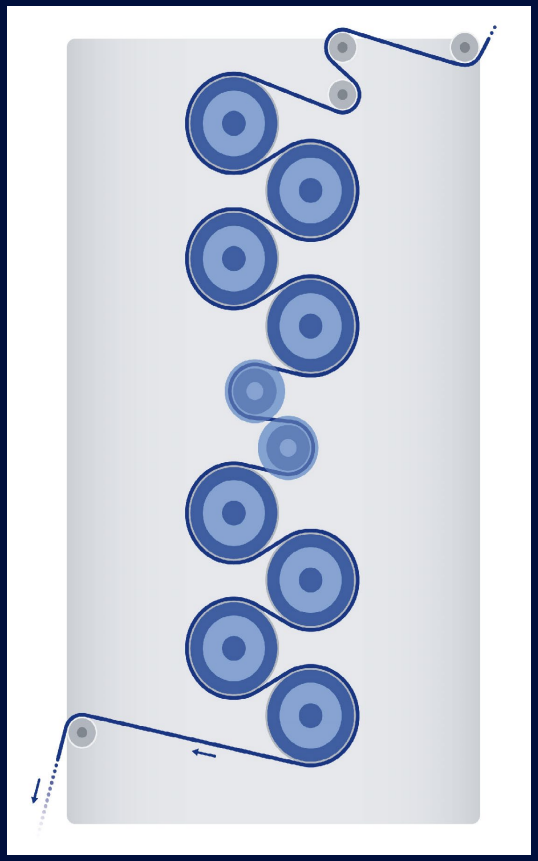


- Barrier properties:
  - Gas barrier
  - WVTR barrier
  - Grease barrier





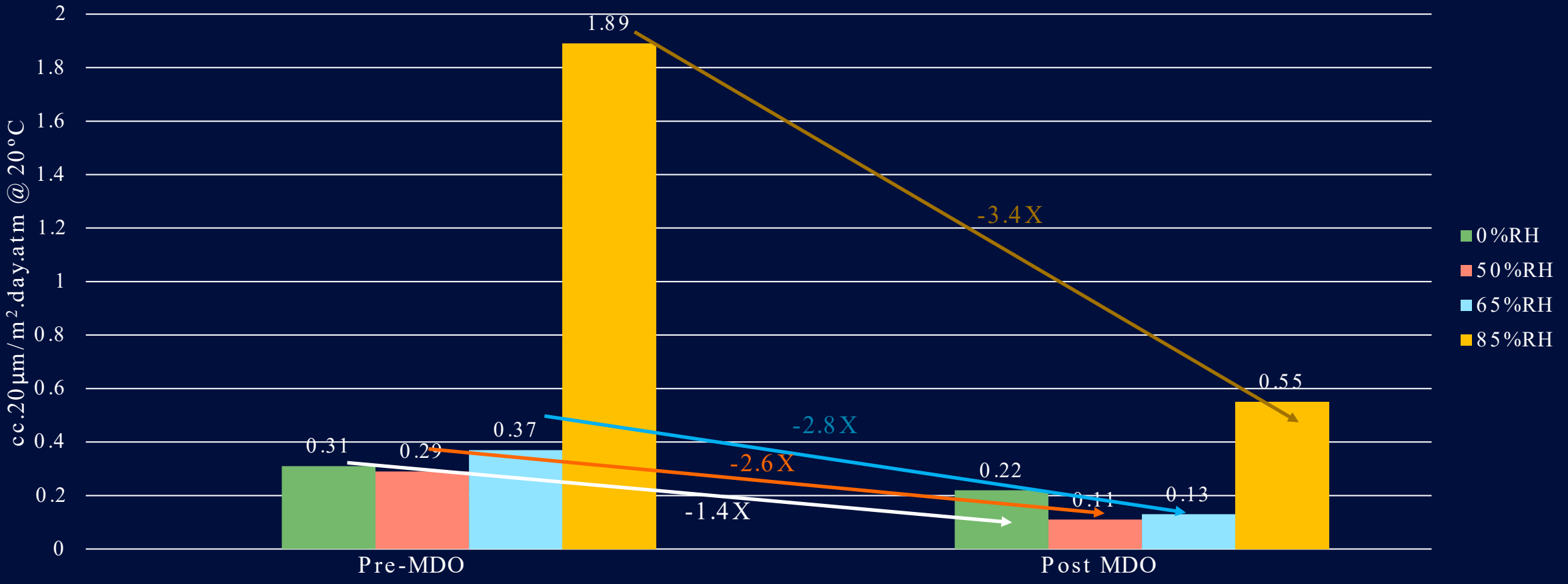
MDO process



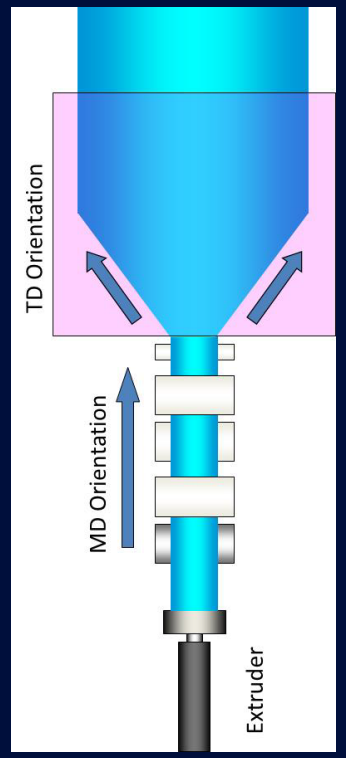
Source; Hosokawa Alpine

MDO process increases the oxygen barrier of EVOH

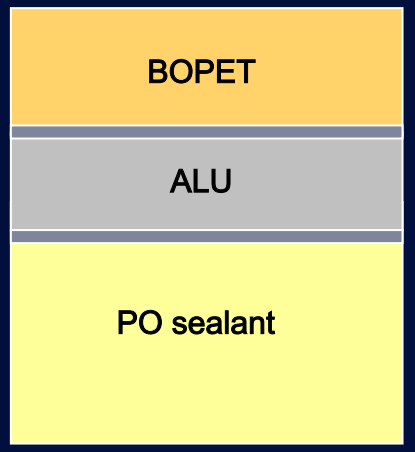
PE film with a layer of EVAL™ F171B (32 mol% et. EVOH) after 6:1 Stretch Ratio



Oriented Monomaterial

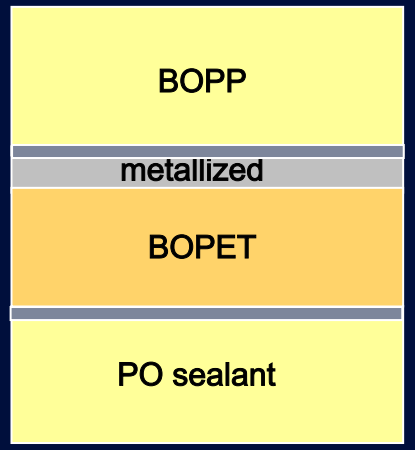


ALU foil based



NOT recyclable
OTR 0.01, WVTR 0.01

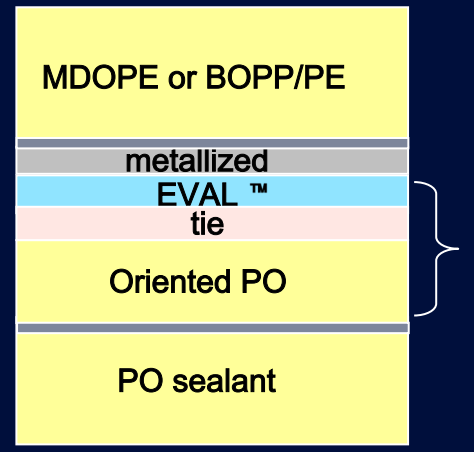
Met-PET based



NOT recyclable
OTR ~1.0, WVTR ~0.5

Mono -PO structure

Met-(B)O-EVOH-PO



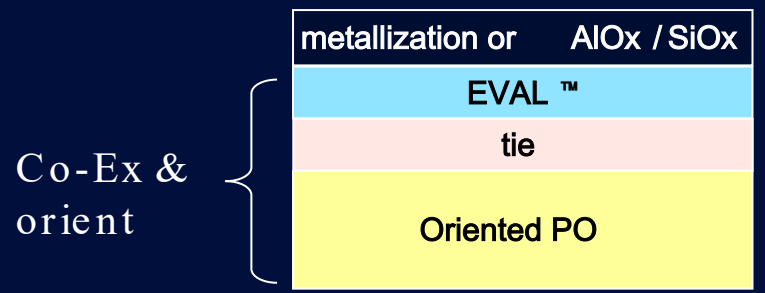
Recyclable
OTR ~0.1, WVTR ~0.1

Benefits of met-EVOH/PO oriented
- Mono-PO (EVOH < 5%)
- Thin EVOH in co-ex for metallization
- High mechanical props due to orientation
- Ultra high barrier (O_2 and H_2O) due to dense metal-EVOH bonding

OTR (cc/m².day.atm)
WVTR (g/m².day)

Other Monomaterial Innovations

- Process: co-ex and mono/bi-axial orientation
- EVOH in the outer/skin layer
- Metallisation or Inorganic coating (off-line)



	WVTR	OTR	Light	Flex crack
Metallization	++	++	++	-
AlOx or SiOx	++	++		--
EVAL™	+	++		++
EVAL™ + metallization	+++	+++	+++	++
EVAL™ + AlOx or SiOx	+++	+++		+

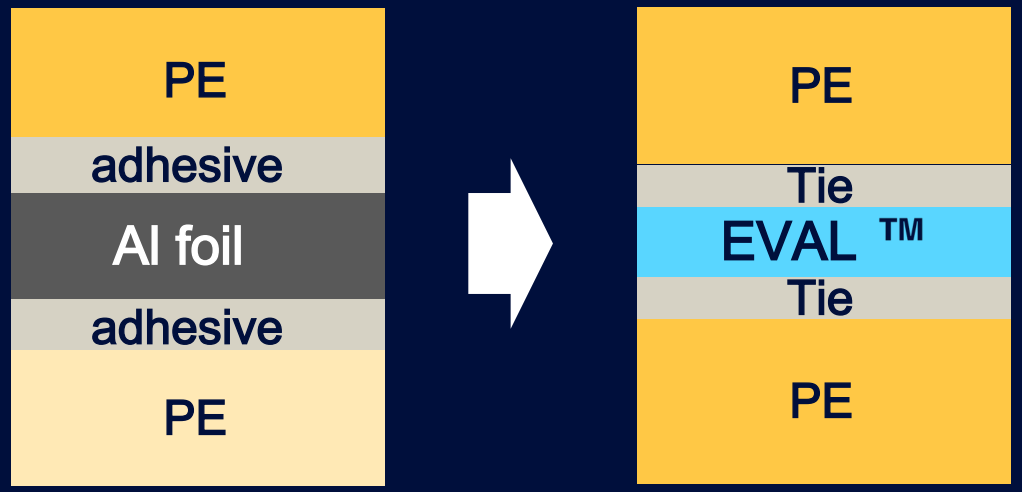
Synergistic effect: the metal atoms bond very well to the polar EVOH surface. In case of pinhole, EVOH is back-up barrier (for O_2)

Design for recycling in practice

Foil replacement in toothpaste and cosmetic tubes

6% EVOH fully compatible with HDPE recycling streams

- European RecyClass
- US Association of Plastics Recyclers (APR)



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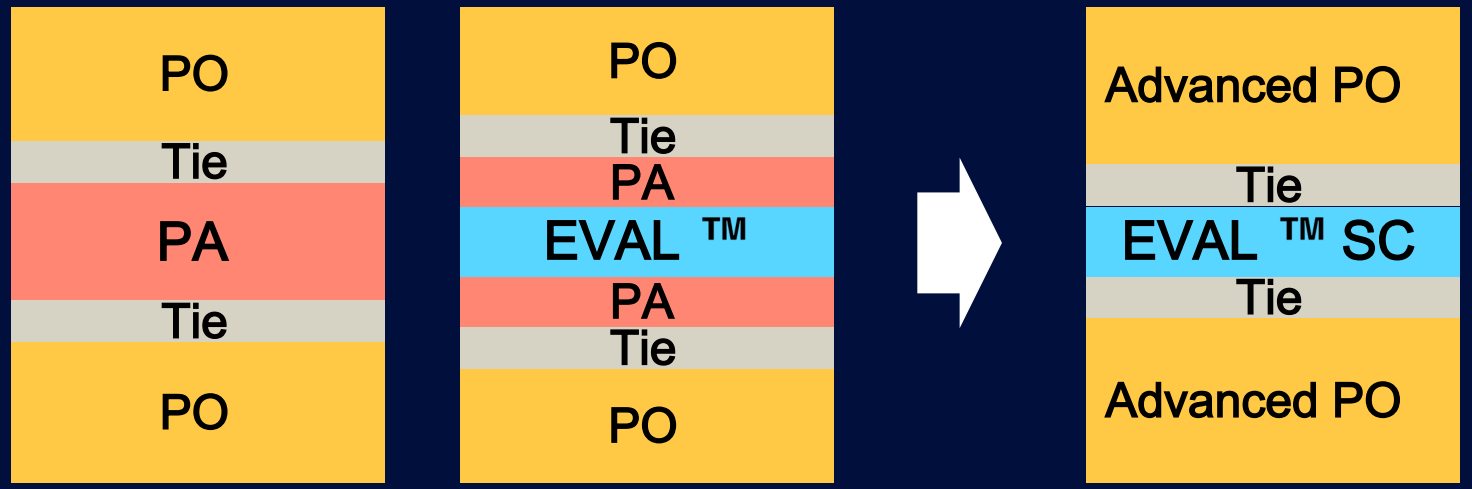
Recyclable form-fill-seal packaging

Design-for-recyclability with latest orientable EVAL™ and PO grades

- Recyclability enhancement to conventional PA/EVOH/PA based structures
- Equivalent deep draw performance



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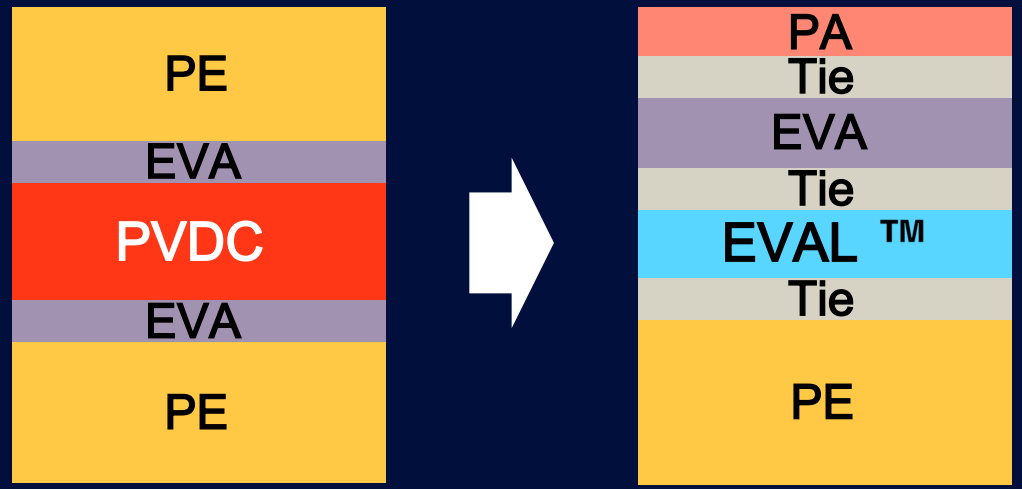
High barrier shrink bag for fresh meat

Thermo-shrinkable, halogen-free film structures with latest EVAL™ grades

- Equivalent performance as PVDC
- Less yellowness and halogen free
- Easier to recycle



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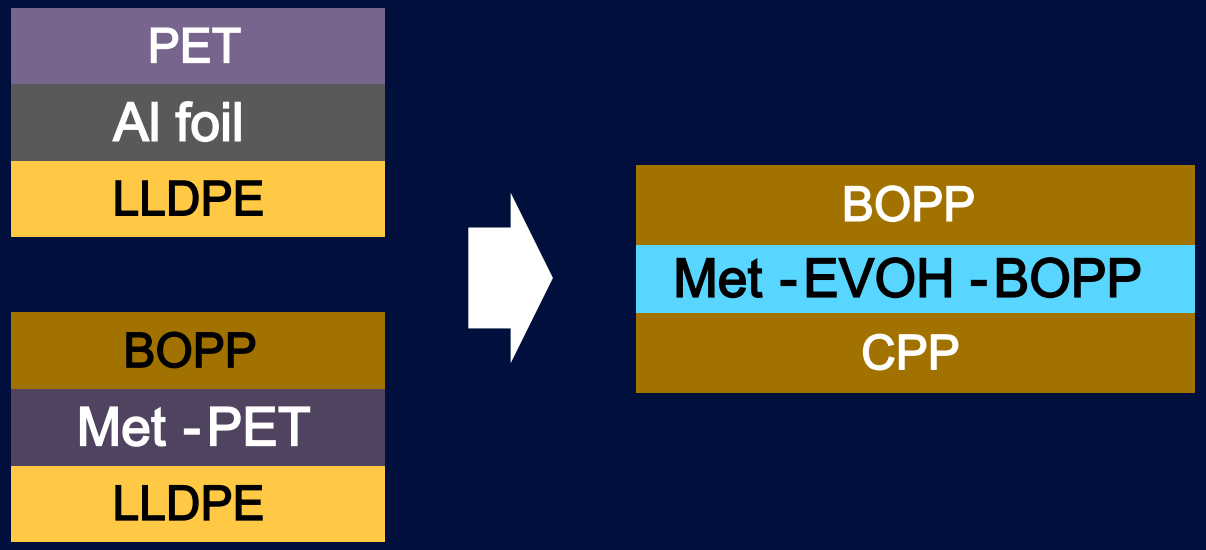
Recyclable monomaterial oriented films

Foil and metalized PET substitute

- PP and EVAL™ co-extrusion and metallization



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Protecting ground water and air quality at the farm, industry and community…

Hydrocarbon, solvent and odor barrier, pollution containment

Conserving food quality from farm to table

High-barrier grain silo bags

- Preserve quality and extend shelf life of grain
- Odor barrier and pest control
- Increase commercial value of grain

Conserving feed quality at the farm

Feed silage cover

- Preserve forage quality
- Reduced mold spoilage
- Aerobic stability

Efficient crops with environmental protection

TIF agricultural fumigation film

- TIF = Totally Impermeable [fumigation] Film
- Enhances fumigant efficacy
- Enables fumigant dose reduction …
- without sacrificing crop yield or quality

Protecting ground water and air quality

High-barrier geomembrane landfill liners and covers

- As a landfill cover EVOH reduces GHG emissions and makes for an effective odor management tool
- As a landfill liner EVOH contains VOCs (BTEX, PFAS, etc.) from permeating into the surrounding soil

Solvent, fuel and chemical containment

Coextruded EVAL™ barrier fuel tanks and agricultural chemical bottles

- Hydrocarbon barrier and solvent resistant

ISCC+ Certified EVAL™

- Kuraray is the first EVOH copolymer producer to receive a corresponding ISCC PLUS certificate for the bio-circular ethylene monomer in its supply chain. The certificate covers, in principle, all EVOH variants that Kuraray produces in Antwerp (EE products).

✓ Renewable C2 = Wood origin

✓ At the moment only partly biobased EVOH
e.i., Ethylene 32mol% → 28wt% Bio based

CONTROLUNION

ISCC PLUS Certificate

Certificate Number: ISCC-PLUS-Cert-DE105-87998701

Control Union Certifications Germany GmbH
Dorotheastr. 30, D-10318 Berlin, Germany

certifies that

EVAL Europe N.V.
Haven 1053 - Nieuwe Weg 1, 2070 Zwijndrecht
BELGIUM

complies with the requirements of the certification system

ISCC PLUS
(International Sustainability and Carbon Certification)

Place of the audit
(if different from the legal address of the system user as stated above; only applicable for traders and traders with storage):

n.a.

This certificate is valid from 02.05.2022 to 01.05.2023.

The site of the system user is certified as:
Polymerization plant

The scope of the certificate includes the following chain of custody options:
(not applicable for paper traders)

Mass balance

Berlin, 02.05.2022
Place and date of issue

CUC Germany GmbH
Dorotheastr. 30, D-10318 Berlin
Tel: +49 (0) 30 509 69 88 - 0
Fax: +49 (0) 30 509 69 88 - 88

Stamp, Signature of issuing party

The issuing Certification Body is responsible for the accuracy of this document.
Version / Date: 1 (no adjustments) / 02.05.2022

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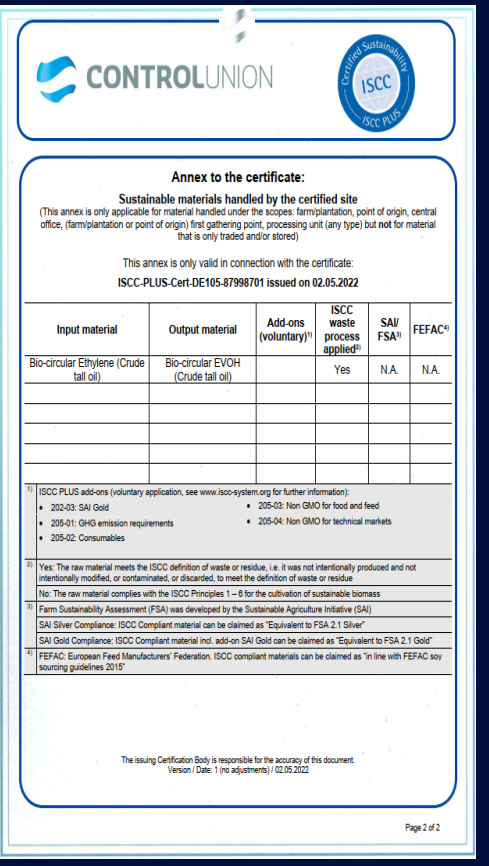

CONTROLUNION

Annex to the certificate:

Sustainable materials handled by the certified site
(This annex is only applicable for material handled under the scopes: farm/plantation, point of origin, central office, (farm/plantation or point of origin) first gathering point, processing unit (any type) but not for material that is only traded and/or stored)

This annex is only valid in connection with the certificate:

ISCC-PLUS-Cert-DE105-87998701 issued on 02.05.2022

Input material	Output material	Add-ons (voluntary)[1]	ISCC waste process applied[2]	SAI/ FSA[3]	FEFAC[4]
Bio-circular Ethylene (Crude tall oil)	Bio-circular EVOH (Crude tall oil)		Yes	N.A.	N.A.

1) ISCC PLUS add-ons (voluntary application, see www.isco-system.org for further information):
- 202-03: SAI Gold
- 205-01: GHG emission requirements
- 205-02: Consumables
- 205-03: Non GMO for food and feed
- 205-04: Non GMO for technical markets

2) Yes: The raw material meets the ISCC definition of waste or residue, i.e. it was not intentionally produced and not intentionally modified, or contaminated, or discarded, to meet the definition of waste or residue
No: The raw material complies with the ISCC Principles 1 – 6 for the cultivation of sustainable biomass

3) Farm Sustainability Assessment (FSA) was developed by the Sustainable Agriculture Initiative (SAI)
SAI Silver Compliance: ISCC Compliant material can be claimed as "Equivalent to FSA 2.1 Silver"
SAI Gold Compliance: ISCC Compliant material incl. add-on SAI Gold can be claimed as "Equivalent to FSA 2.1 Gold"

4) FEFAC: European Feed Manufacturers' Federation. ISCC compliant materials can be claimed as "in line with FEFAC soy sourcing guidelines 2016"

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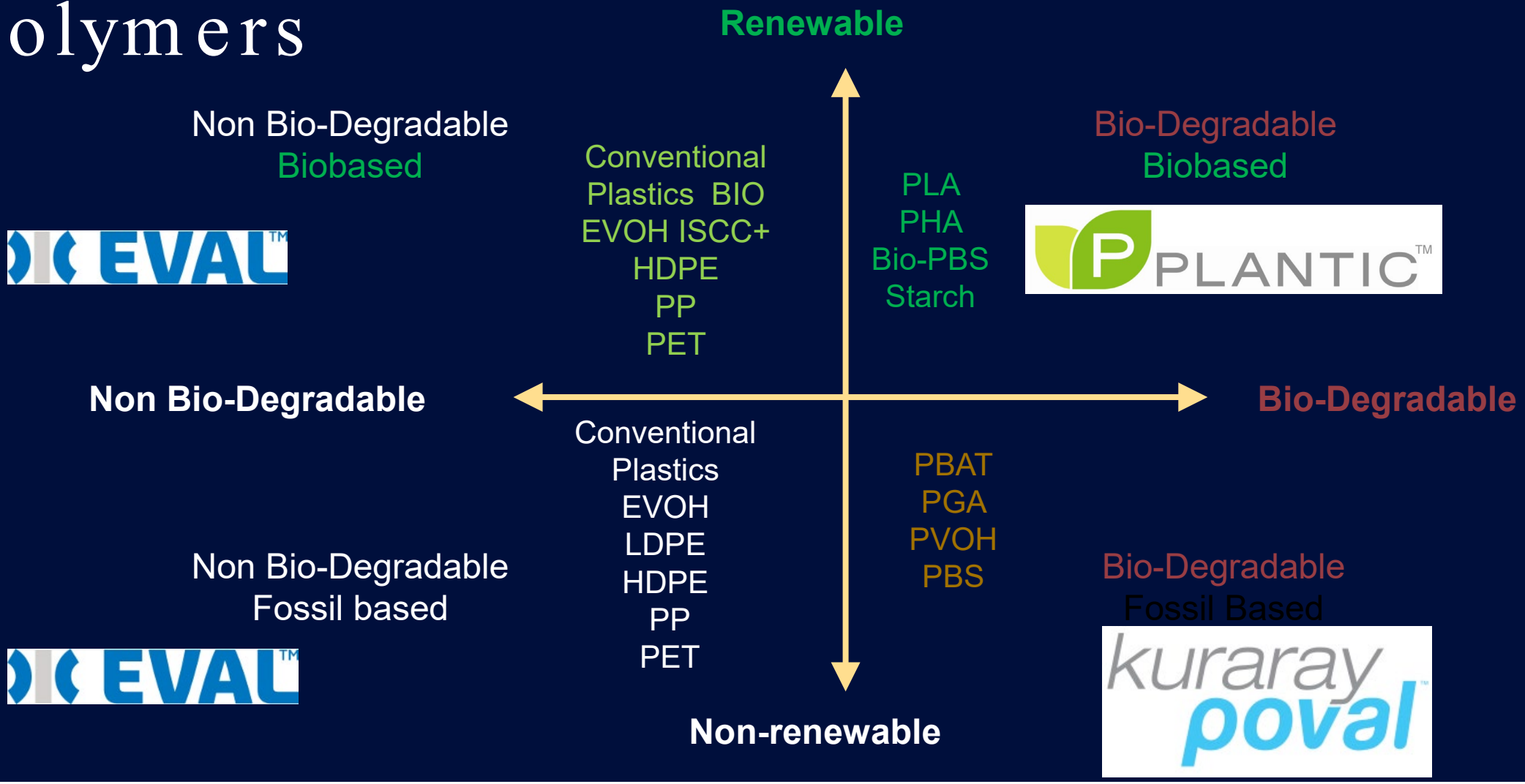
Bio EVAL™ available from Europe now and from the Americas soon

*ISCC: International Sustainability & Carbon Certification

Renewable Resource and Biodegrable Polymers

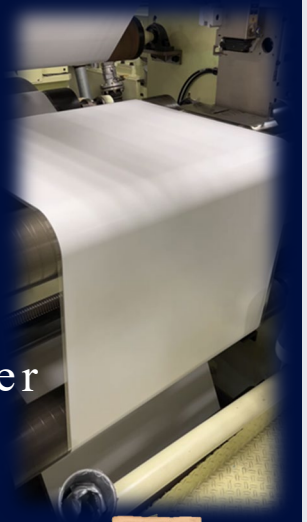



PLANTIC™ resin


Extrusion

PLANTIC™ Film


Lamination


Paper


PET/ Plantic /PET

PE/ Plantic /PE


Paper/ Plantic /PE
Paper/ Plantic /PBS, PHA, etc.

kuraray

What are PLANTIC™ products?

High barrier Biobased Repulpable Thermoplastic

1. Resin in Pellet Form

- Extrudable at low temperature (100℃)
- Design for Thin (20μm) extrusion coated layers
- Low shear screw design
- Suitable for Repulpable Paper Substrates

2. Film for Lamination

- Monolayer 70μm films
- Thermoformable
- Dispersible and biodegradable in water
- Home compostable
- Can be used alone or laminated in combination to many substrates (conventional plastics, paper, bioplastics, compostables)

3. Practical points

- Water resistant skin layers are needed to provide a useful packaging solution
- The solubility of Plantic can be leveraged to separate PET or PE skins by density in recycling processes

Summary

Reinforce and differentiate your business with Kuraray…

Sustainable possibilities through Kuraray's high-barrier EVAL™ EVOH

1. **Who is Kuraray and what is EVAL™ EVOH?**
   Leader in performance-based polymer and specialty materials technologies

2. **Extended food shelf-life with minimal packaging**
   Protecting quality and reducing food waste, in minimal and recyclable packaging

3. **EVOH, the recyclable barrier of choice**
   Preferred recyclable substitute for PVC, PVDC and foil

4. **Beyond the package, sustainable industrial solutions for the environment**
   Hydrocarbon, solvent and odor barrier, pollution containment

Our Plantic™ technology offers new opportunities for novel biosourced barrier packaging

Understanding your challenges & next steps

For people and the planet, pioneering sustainable packaging solutions that improves the environment and enhances the quality of life throughout the world

Reinforce and differentiate your business with Kuraray…

1. World's leading commercial portfolio of gas barrier chemistry
2. Over fifty years of experience with EVAL™ EVOH high-barrier packaging
3. Over the last decade Plantic can provide a biodegradable barrier solution

Partner with us

EXPERTISE | ACTION

Thank you!

Edgard Chow
edgard.chow@kuraray.com
Director of Technical Service & Development

Kuraray America, Inc. – EVAL Business Unit
3700 Bay Area Blvd., Suite 680
Houston, TX 77058
USA

→eval.kuraray.com

kuraray