THE END-OF-LIFE CHALLENGE FOR FLEXIBLE PACKAGING: MULTILAYER FILMS, BARRIER STRUCTURES AND POUCHES

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OUTLINE

1) **Advantages of flexible and pouch packaging over rigid packaging and market transitions**

2) **Difficulty of mechanical recycling and/or recovery of flexible, barrier and pouch packaging**

3) **Environmental opposition to flexible and pouch packaging**

4) **Packaging industry actions and responses**

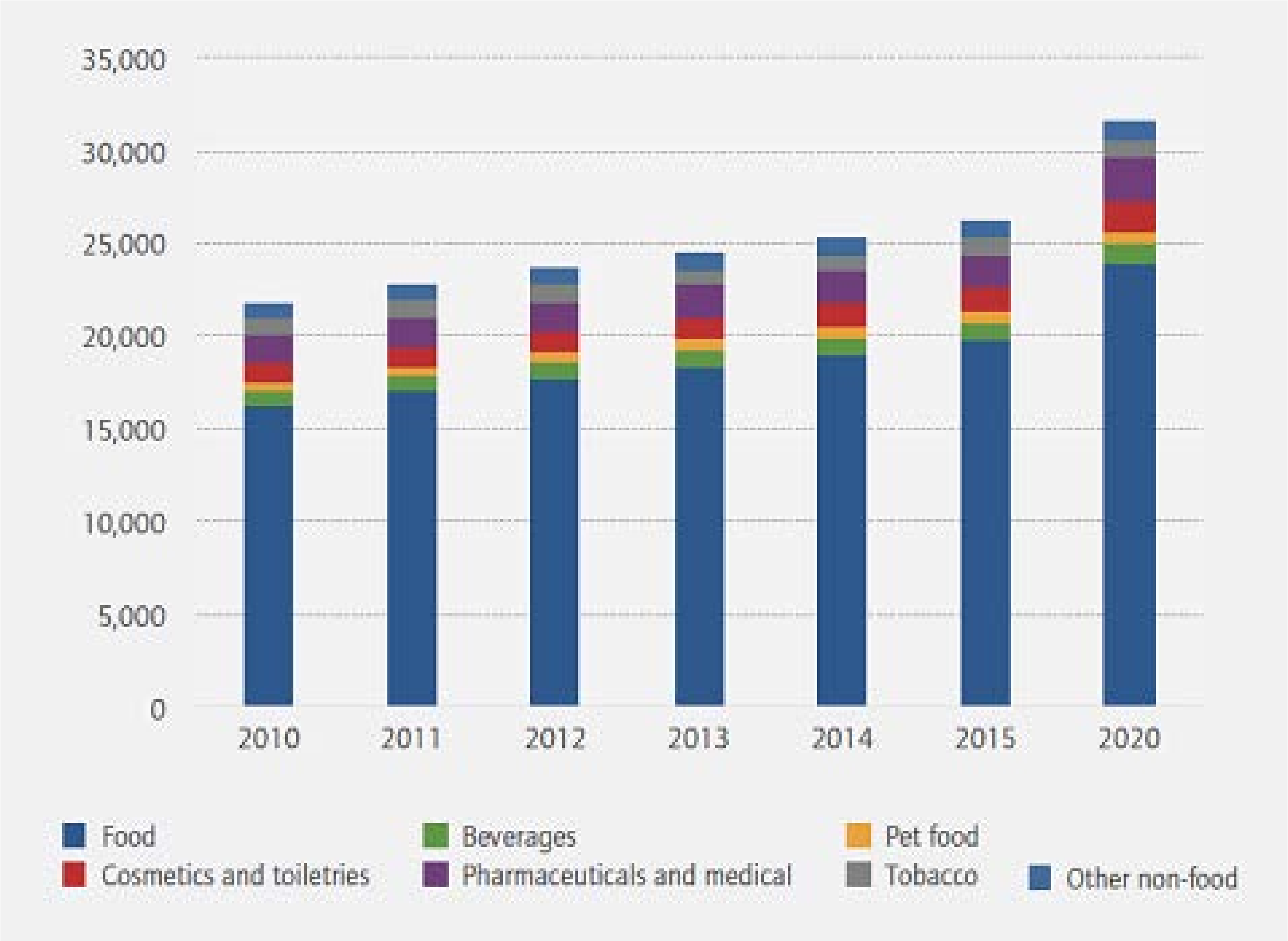
5) **New materials, recycling and recovery systems development**

6) **Conclusions, future developments and summary**

TRANSITION FROM RIGID TO FLEXIBLE PACKAGING

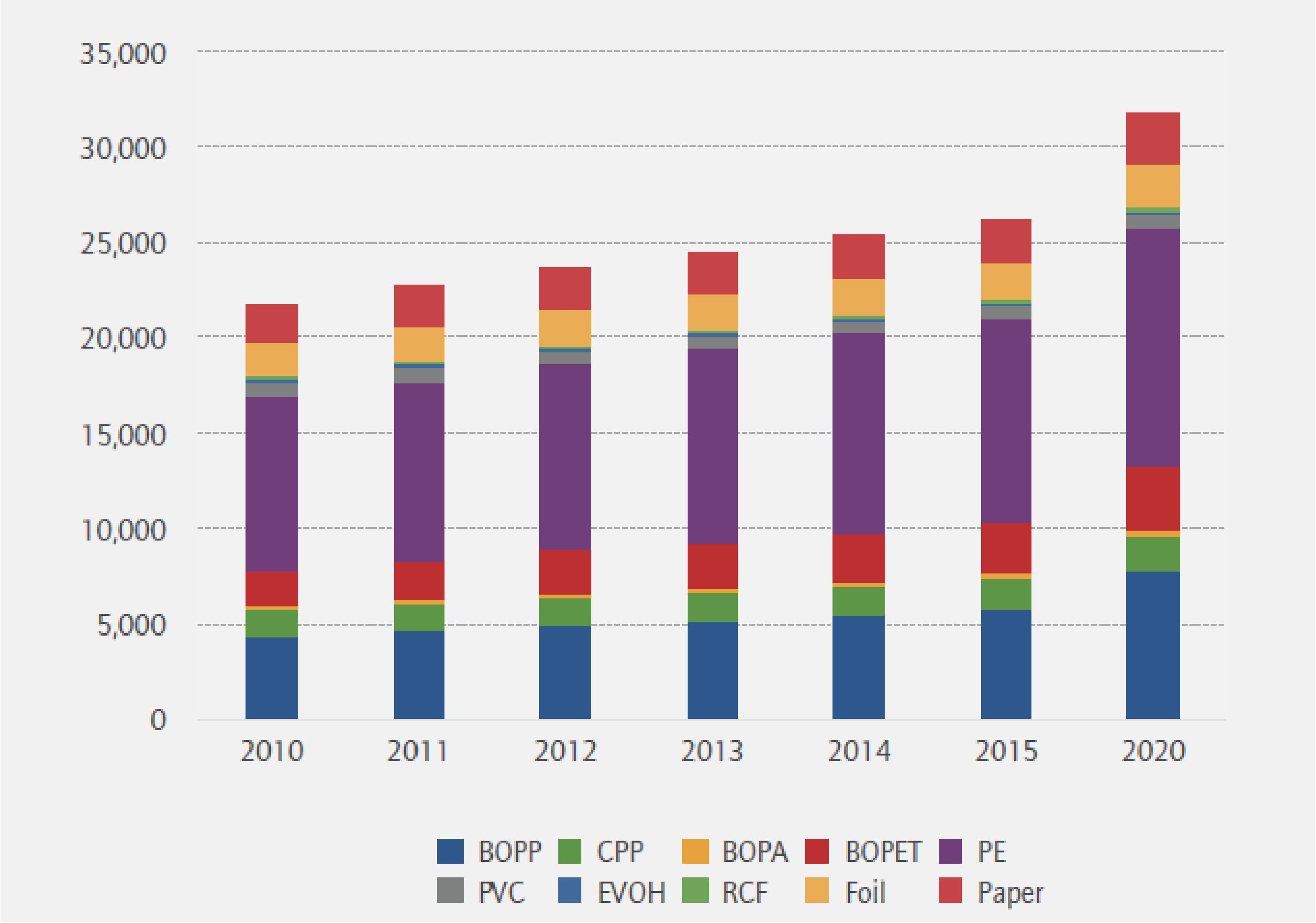
- **Use of flexible packaging increasing rapidly worldwide in market percentage and absolute terms**
- **Global market \$98bn 2016 projected to reach up to \$248bn by 2020 (SmithersPira), 3.4% CAGR**
- **Gaining market share from other formats such as rigid packaging in many applications**
- **Continual encroachment in FMCG areas, particularly food, beverage, pharmaceutical, previously served by other packaging formats, e.g. motor oil, paint, baby food, tuna fish, pet food, where product freshness is key.**

FORECAST WORLD CONSUMER FLEXIBLE PACKAGING CONSUMPTION BY APPLICATION (Ktpa)



Source:
SmithersPira

FORECAST WORLD CONSUMER FLEXIBLE PACKAGING CONSUMPTION BY MATERIAL (Ktpa)



Source: SmithersPira

FLEXIBLE PACKAGING ADVANTAGES/DRIVERS

- **Multilayer flexible packaging superbly designed for first-life: minimized content spoilage; long shelf-life; reducing costs; consumer convenience; easy opening**
- **Less material used than other formats (the minimum possible) and much less packaging waste - only 2% of US municipal solid waste is flexible packaging**
- **Less energy for production and lower transport costs**
- **Lower environmental impact (LCA) and carbon footprint (GHG emissions) than other formats**
- **High barrier protection keeps products fresh for longer, reducing product waste, and enhances flavors. Barrier tunable to meet product and shelf life needs. Can be retorted and hot-filled to replace glass and metal.**

FLEXIBLE PACKAGING ADVANTAGES/DRIVERS

- **Can be tailored to specific product and size and continual development of new and improved designs, e.g. with resealable tabs, handles, zips, spouts, dispensers.**
- **Can be readily printed, decorated and coded without use of separate labels and allows instant changes**
- **Flexible Packaging Europe – if all non-flex packaging were replaced by flexible, it would save 26 million tpa packaging entering waste stream, about a 77% reduction in total weight recycled or landfilled.**
- **Flexible packaging provides the same functionality as many other formats but uses far less resources. Its resource efficiency will be even further increased by optimization of end-of-life recovery**

FLEXIBLE PACKAGING END-OF-LIFE

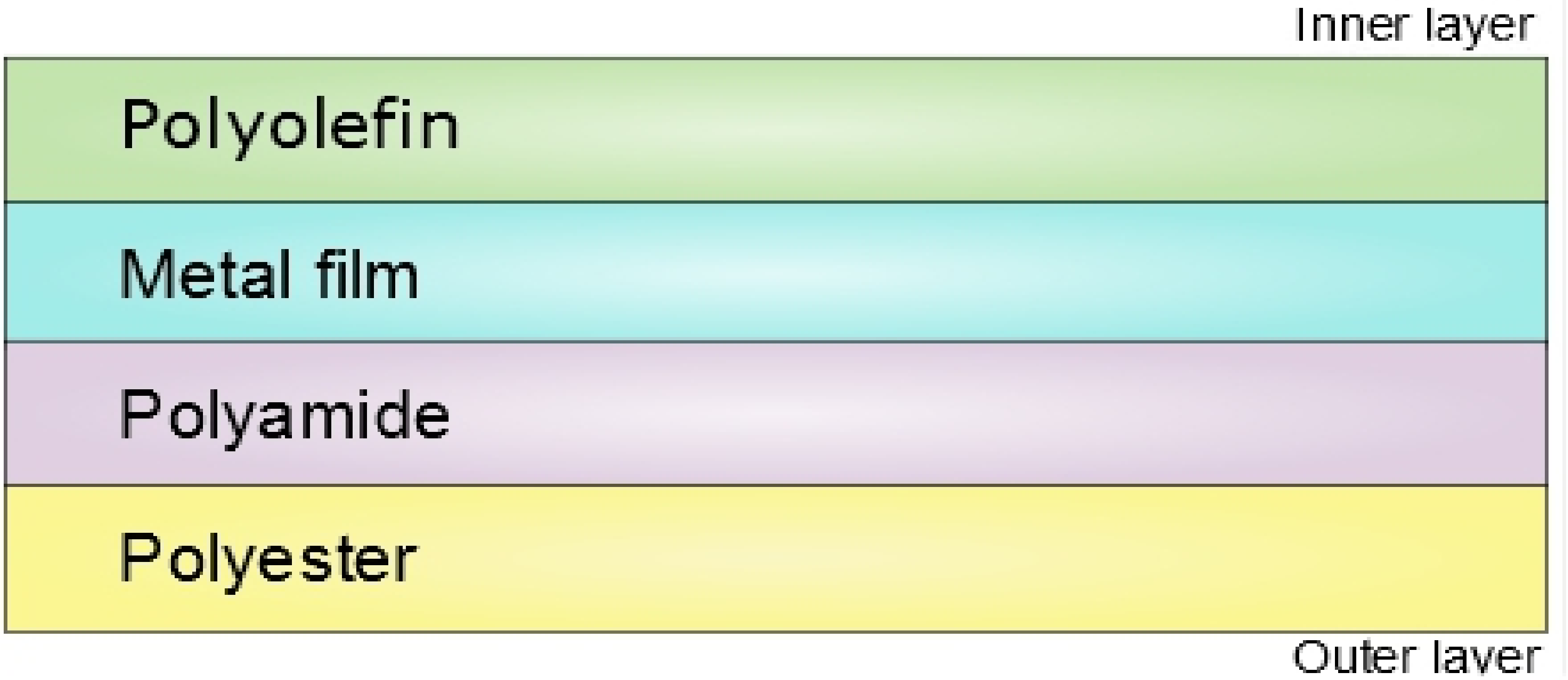
- Flexible packaging uses little material and hence generates less waste than other formats

- “Flexible packaging has been so successful because of its material efficiency. It creates a cascade of environmental benefits throughout the entire value chain, and avoids waste at source. By working collaboratively towards a recovery option for flexible packaging, we can further improve the environmental credentials of this packaging type.”

  Dr. Gerald Rebitzer, Sustainability Director, Amcor

STRUCTURE OF FLEXIBLE PACKAGING

- Flexible packaging can be monolayer, coated monolayer or multilayer
- The layers are different materials with specific functions in the structure and can include outer "bulk" layers, barrier layers, tie layers and seal layers



FLEXIBLE PACKAGING NEGATIVE FACTORS

- **Associated problems of disposal, littering, ocean pollution, reuse and recycling because of:**
  - **Lack of recycling infrastructure, largely because of problems of collection, sorting and recycling of films and multilayer laminates, particularly for barrier packaging and post-consumer waste**
  - **Difficulty in economically mechanically recycling multilayer structures, so that they generally end up in landfill or are incinerated to recover energy content**
  - **Common food waste contamination, often 10-20% package weight**
  - **Slow environmental degradation of many of the materials used**
  - **Continuing visibility challenge with flexible packaging, even though it uses much less material than other formats**

- **This is becoming a significant problem due to NGO opposition and consumer environmental and sustainability concerns**

ENVIRONMENTAL OPPOSITION

- **Adversarial campaigns instituted by environmental NGOs, including As You Sew, Upstream, 5 Gyres, NRDC, Greenpeace and Sierra Club, versus food companies over pouch packaging, e.g. Kraft Capri Sun**
- **Pressure being placed on food companies and their shareholders to set up take-back programs or stop using pouch packaging all together**
- **NGO position: it is not acceptable to produce a product designed to be disposed of, and urging extended producer responsibility legislation**
- **Rise of Circular Economy principles**
- **This is based on equating sustainability and mechanical recyclability and discounting the significant sustainability advantages of flexible packaging**

INDUSTRY RESPONSES

- **Industry is serious and concerned about ecological challenges with flexible packaging and is actively seeking effective and economic solutions**
- **This includes economic end-of-life collection, sorting, recycling and recovery processes**
- **Industry is working to educate consumers that:**
- **Mechanical recycling and sustainability are NOT synonymous; and**
- **The superior sustainability and eco-friendliness of flexible packaging lie in its minimal materials, transport and energy use and reduction in waste of the packaged products, especially food waste, so that it saves more resources than it uses**

INDUSTRY RESPONSES

- **Food, food packaging and recycling industries are developing systems to keep multilayer flexible packaging from landfill:**
  - **Improved materials and designs to aid recycling**
  - **Economic end-of-life recycling and recovery processes**
- **Industry associations and action groups are working to promote this new end-of-life infrastructure, including:**
  - **American Chemistry Council (Materials Recovery for the Future; Flexible Film Recycling Group; WRAP Recycling Action Program)**
  - **Sustainable Packaging Coalition (GreenBlue)**
  - **APR (Film Reclamation Committee)**
  - **Recycling Partnership**
  - **Flexible Packaging Association (Energy Bag Project)**

NEW TECHNOLOGIES FOR END-OF-LIFE PROCESSES FOR FLEXIBLE PACKAGING

Six major approaches:

- **Development of improved collection, marking and sorting systems, e.g. EU CEFLEX project, US Recycling Partnership, Sustainable Packaging Coalition, Materials Recovery for the Future**
- **Delamination of multilayer packaging systems to economically separate and recover film layers: e.g. Saperatec, Enval**
- **Chemical recycling processes: e.g. APK, Fraunhofer , BioCellection**
- **Anaerobic and pyrolytic waste-to-energy processes:**
- **Westinghouse, Advanced Plasma Power, Concord Blue Energy**
- **Anaerobic and pyrolytic waste-to-fuel, waste-to-chemicals and waste-to-monomers processes:**
- **Suez, Agilyx, Recycling Technologies, Lanzatech**
- **Development of mechanically-recyclable monolayer and coated barrier systems and compatibilizers, e.g. DowDuPont, Nova, DIC**

WRAP RECYCLING ACTION PROGRAM

- **Public-private partnership led by American Chemistry Council in association with APR, Sustainable Packaging Coalition and Canadian Plastics Industry Assoc. (www.plasticfilmrecycling.org)**
- **Stakeholders include local and state governments, retailers, and material recovery facilities (MRFs)**
- **Goal to educate consumers about what types of plastic film are recyclable, and how and where to recycle it**
- **Successful WRAP campaigns across the U.S. and Canada have helped communities keep plastic film out of MRFs and increased plastic film collections for recycling at drop-off locations**
- **Sponsors: Dow, ExxonMobil, Chevron Phillips, LyondellBasell, P&G, SC Johnson, Berry, Sealed Air, AERT, Avongardinnovative, Trex, PAC, Pregis, Prime Plastic, Printpack**

RECYCLING PARTNERSHIP (US)

- **Public-private partnership (www.recyclingpartnership.org)**
- **Consortium of brand owners, packaging companies, raw material suppliers, haulers, trade associations, local and state governments**
- **Helps local governments and solid waste authorities with 4,000 or more households upgrade cart-based curbside recycling collection.**
- **Has helped leverage >$20 million of new infrastructure and placed 400,000 new recycling carts in communities across the US, including St. Paul, MN, Greenville, SC, East Lansing, MI, Portland, ME, Santa Fe, NM, and Richmond, VA**
- **Funding partners: Alcoa, Amcor, ACC, American Forest and Paper Association, APR, Ball, Carton Council, Coca-Cola, SPI and Sonoco**
- **Goal is to transform US curbside recycling system by making recycling easier for the consumer, make community recycling programs more accessible and efficient, and engage full recycling supply chain from local government to industry end markets, haulers, MRFs and converters in a shared responsibility approach**

MATERIALS RECOVERY FOR THE FUTURE

- **Consortium of brand owners, packaging companies and packaging industry organizations, led by American Chemistry Council**
- **Sponsors: Dow Chemical, Pepsico, P&G, Nestle, Sealed Air, S.C. Johnson, Amcor, APR, Flexible Packaging Association and SPI**
- **Goal to increase recycling rates, divert flexible packaging from landfill and create mainstream recovery processes and systems**
- **Research by Resource Recycling Systems evaluated effectiveness of existing MRF sorting technologies, e.g. screens and optical scanners, in sorting flexible packaging. Showed that modified existing MRF technology can identify and sort flexible plastic packaging at useful efficiency levels.**
- **Further research to define the recovery system of the future by identifying additional technologies for plastics reprocessing to ensure mechanical recycling of resins that have current end markets.   Now focused on further refinements to sorting technology, economic feasibility, assessing end-use markets for the recyclates, and developing a demonstration recovery facility**

CEFLEX PROJECT (EUROPE)

- CIRCULAR ECONOMY FOR FLEXIBLE PACKAGING
- Collaborative project of consortium of companies representing entire value chain of flexible packaging in Europe
- Now includes 43 companies and organizations
- Building on results of previous REFLEX (UK) and FIACE (EU) projects with goal to make flexible packaging even more valuable in circular economy
- Aim to increase collection and recycling of flexible packaging in all European countries, and develop design guidelines for flexible packaging and end-of-life infrastructure to maximize overall resource efficiency and optimize recyclability.

Project Stakeholders

CEFLEX
A CIRCULAR ECONOMY FOR FLEXIBLE PACKAGING

- BOREALIS Keep Discovering
- DOW
- DUPONT
- Henkel
- HYDRO infinite aluminium
- PlasticsEurope
- sappi
- SIEGWERK

- amcor
- Constantia Flexibles
- ecolean
- FLEXIBLE PACKAGING EUROPE
- Huhtamaki
- IMMER
- Jindal Films
- mondi
- plastotecnica
- POLYPOUCH
- SealedAir Re-imagine
- TORAY Innovation by Chemistry
- WIPAK

- Barilla
- Hill's Transforming Lives
- M&S EST. 1884
- Nestlé
- PEPSICO
- pladis
- P&G
- Unilever

- attero
- mtm plastics die Aufwerter – the Upcyclers
- PYRAL
- suez
- TÖNSMEIER Wir holen das Beste raus!
- ecoblue renewing resources
- DerGrünePunkt
- APK ALUMINIUM UND KUNSTSTOFFE AG
- newcycling

- BOSCH Invented for life
- BRÜCKNER MASCHINENBAU
- EREMA GROUP
- Expra Extended Producer Responsibility Alliance
- TOMRA SORTING SOLUTIONS RECYCLING

Project Goals & Deliverables

- **By 2020** flexible packaging will be recycled in an increasing number of European countries, facilitated by project CEFLEX through:
  - The development and application of robust Design Guidelines for both flexible packaging and the “End of Cycle” infrastructure to collect, sort and recycle them
  - The identification and development of sustainable end markets for the secondary materials recycled from flexible packaging

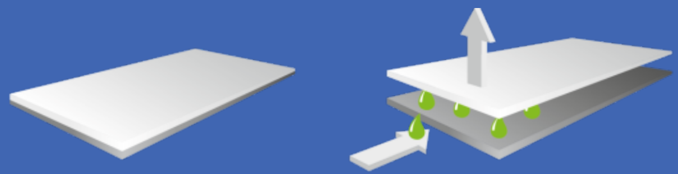
- **By 2025** the development of a collection, sorting and reprocessing infrastructure for post-consumer flexible packaging across Europe, facilitated by project CEFLEX through:
  - A business case for collecting all flexible packaging
  - Proof of principle from successful pilot projects

DELAMINATION PROCESSES FOR FLEXIBLE PACKAGING

SAPERATEC DELAMINATION PROCESS

- **German start-up company (www.saperatec.de)**
- **Low-energy mechanical recycling process for multilayer packaging**
- **After initial shredding step, proprietary surfactant-based microemulsions are used to break up and separate the layers**
- **The microemulsion is then reusable**
- **Works with formats incorporating plastics, paper and aluminum (e.g. PE/Al, PP/Al, PE/PET) but presently not being used for post-consumer waste because of sorting problem**
- **High purity plastic components, aluminum and cellulosic fibers can be separated out for reuse**
- **Originally developed for rigid packaging such as beverage cartons, but now being extended to flexible systems**
- **Pilot plant in operation in Germany since 2014 and first large scale recycling center (18ktpa) scheduled for 2018 after funding round**
- **Still have challenge of collection and sorting barrier packaging in requisite volumes**

Saperatec - Recycling of flexible multilayer packaging



Specifically designed separation fluids diffuse at boundary surfaces and enable delamination/de-bonding

USPs:

- No loss of applied materials/layers and
- High purity of the recovered materials lead to
  - ➡ Material recycling (not thermal recovery),
  - ➡ Contribution to recycling quota,
  - ➡ Max. added value out of the material.
- Circulation of separation fluid.

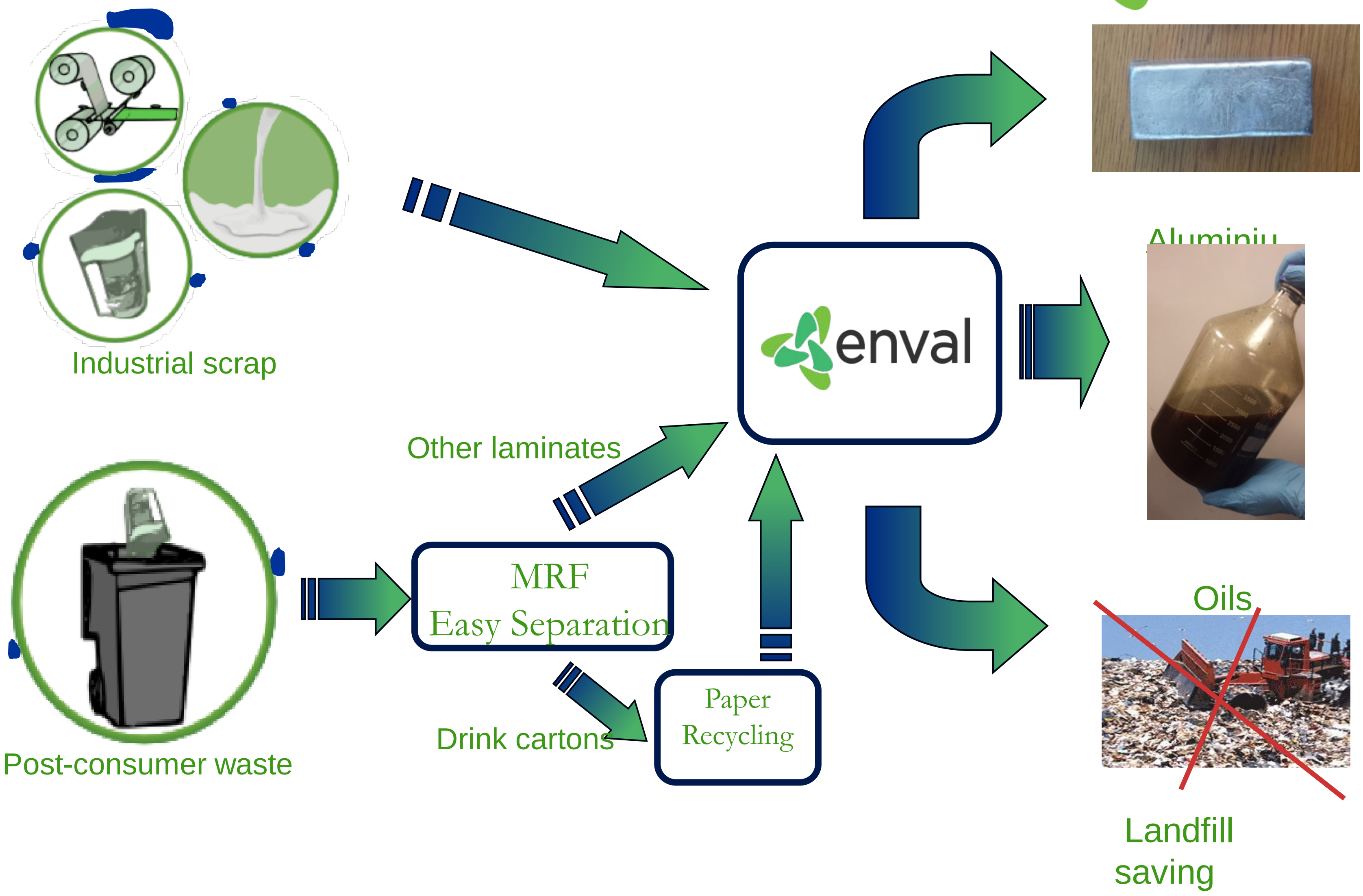
- Realized in **pilot scale** (ca. 500 m² floor space).
- Currently in process of scale-up/industrialization.
- Promising **draft LCA** of the designed process underline advantages in comparison to incineration as well as virgin material production.

Typical LD-PE/Alu/PET pouch-material after delamination

ENVAL PROCESS

- Spin-off from Department of Engineering, Cambridge University (UK) (www.enval.com)
- Provides environmentally favorable end-of-life process for complete recycling of barrier packaging, pouches and tubes based on plastic/aluminum laminates
- Construction of commercial-scale plant supported by Nestle, Kraft and Mondelez
- Uses continuous anaerobic microwave-induced pyrolysis of shredded laminate over a carbon bed, reaching temperatures of over 1,000°C, to recover 100% of clean aluminum from barrier flexible packaging ready for reuse
- Plastic components are converted to fuel gas, used to power the process, and higher alkane liquids (similar to diesel fuel)
- Still have challenge of collection and sorting Al-based barrier packaging in requisite volumes

The Enval Process



Enval today

Alconbury plant


Alconbury plant


Aluminium flakes from the process


Aluminium ingot produced from the flakes

WASTE-TO-ENERGY SYSTEMS

- Anaerobic or controlled (starved) oxygen content thermal pyrolysis or plasma pyrolysis of waste materials, including packaging
- Plasma gasifiers operate under oxygen-starved conditions at temperatures exceeding 3,000°C, allowing complete removal of tars. Non-plasma thermal fluidized-bed gasifiers operate at 8-900°C
- The waste is converted to water, hydrogen and carbon monoxide (syngas)
- Syngas can be used as fuel for high efficiency gas turbines and fuel cells for energy generation, as a substitute natural gas, and for conversion to liquid fuels and downstream chemicals

NOTE:

- Pyrolysis is quite different from incineration (an aerobic process). It has low emissions and greenhouse gas footprint and yields useful downstream chemical products. No dioxins are produced.
- Avoids the necessity to identify and separate types of packaging waste materials

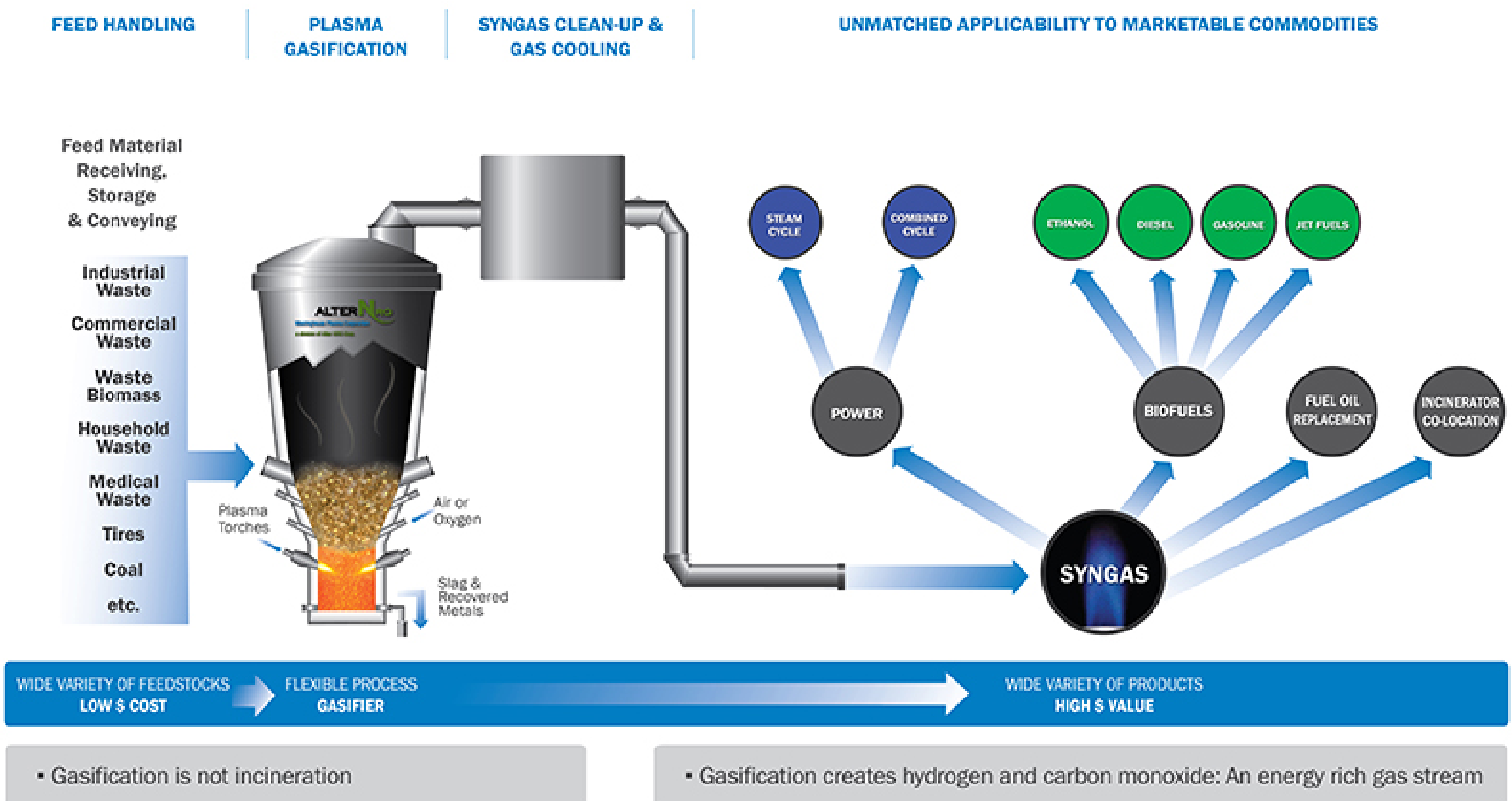
WASTE-TO-ENERGY SYSTEMS

- **Westinghouse Plasma (www.westinghouse-plasma.com): Plasma pyrolysis of waste to clean syngas (CO + H2). Units operating in UK, China, India, Japan**
- **Advanced Plasma Power (www.advancedplasmapower.com): Gasplasma® two stage conversion process for fluid bed gasification and plasma treatment to produce clean syngas. Demonstration unit in Reading UK and commercial plant under construction in Swindon UK.**
- **Concord Blue Energy (www.concordblueenergy.com): Closed-loop two-stage anaerobic pyrolysis process, now licensed to Lanzatech. Plants in US, Japan, UK, Germany and India, and global manufacturing partnership with Lockheed Martin**

- **Advantage of pyrolytic processes is that packaging can be mixed in with other refuse, biomass etc so no sorting is required and no market needs to be found for the recyclate**
- **Disadvantage is that some NGOs and consumers do not consider this true recycling**

WASTE-TO-ENERGY SYSTEMS

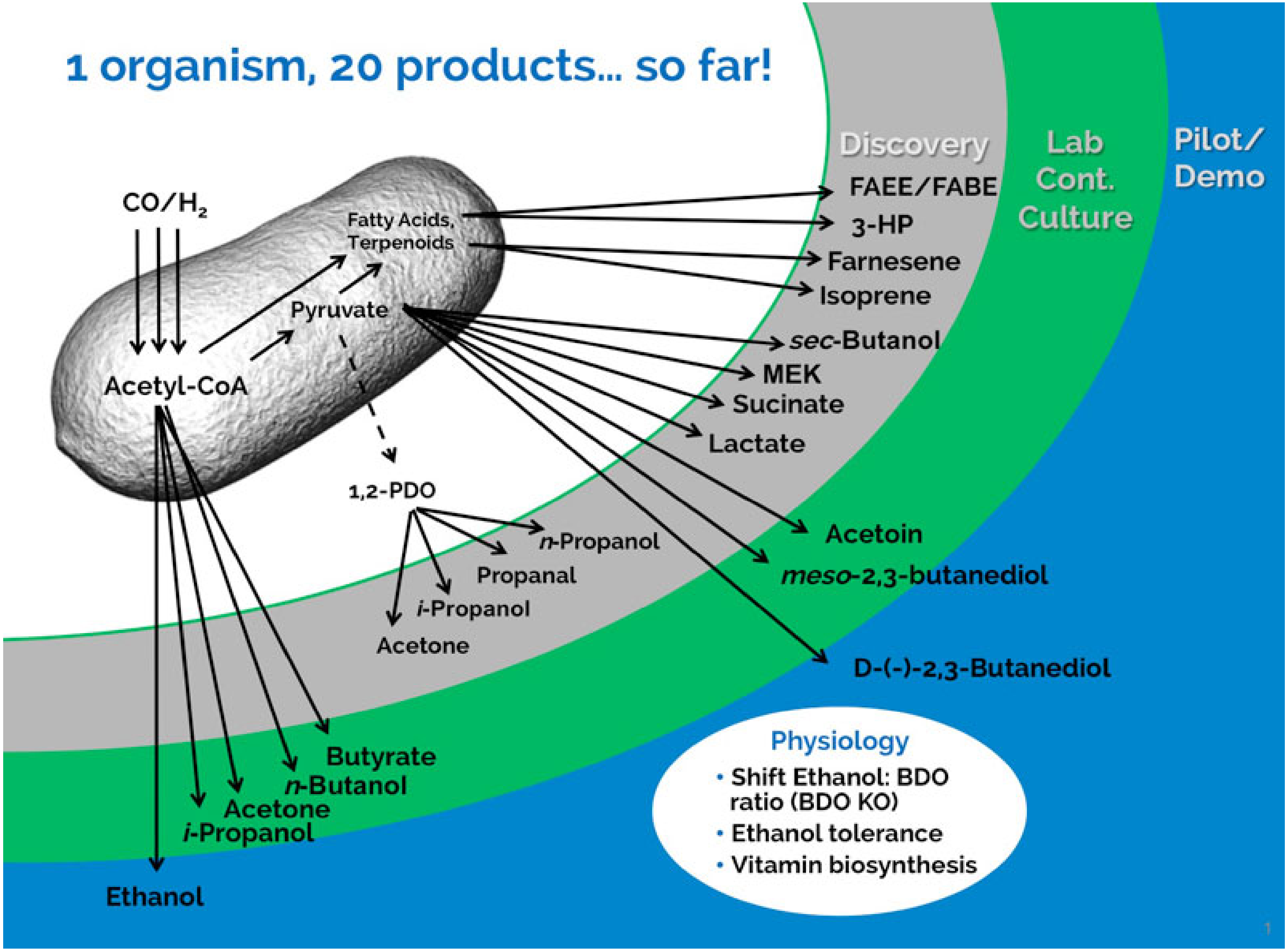
- **Plasma pyrolysis:**
- **Westinghouse Plasma Corporation**



WASTE-TO-FUEL, WASTE-TO-CHEMICAL AND WASTE-TO-MONOMER SYSTEMS

- **Processes developed and implemented to convert plastics into hydrocarbons, with net energy yield. These include:**
- **Agilyx: Joint development program with Ineos Styrolution for waste polystyrene conversion to styrene monomer.**
- **Recycling Technologies: Waste plastic and other general waste thermally depolymerized to low-sulfur Plaxx light and heavy oils and waxes using fluidized bed cracker and regenerator. Pilot facility in Swindon, UK; commercial plant 2018 in Scotland.**
- **Pyrocrat Systems (India): catalyzed pyrolysis process**
- **Plastic Advanced Recycling Corporation (PARC): Pyrolytic conversion of waste plastic and rubber to high quality fuel oil. Three plants operating in China**
- **Plastic2Oil: Waste plastic pyrolytic conversion to low-sulfur fuel**
- **Lanzatech: Waste carbon monoxide from steel plants and syngas converted to platform chemicals and bioethanol fuels by gas-phase fermentation**

LANZATECH PRODUCT PORTFOLIO



CHEMICAL RECYCLING PROCESSES

- **APK AG “Newcycling” chemical dissolution process for multilayer plastics to polymers with properties close to virgin materials and competitive economics**
  - **Uses proprietary solvent technology to separate the different polymer types in multilayer structures**
  - **PE is dissolved out, recovered from solution and pelletized**
  - **First commercial plant will startup September 2018. 5 plants are planned for southeast Asia. CEFLEX partner.**
- **Fraunhofer “CreaSolv” process**
  - **Target polymers selectively dissolved from plastic waste and contaminants removed from the solution using special purification methods.**
  - **Customized solvent formulations developed for a wide range of plastic wastes and target polymers and used solvents are recycled.**
  - **Purified polymer recyclates have properties akin to virgin polymers.**
  - **Presently less advanced than APK but supported by Unilever**

BIOCELLECTION PROCESS

- **Startup California company (www.biocellection.com)**
- **Low-energy, low-temperature recycling process involving:**
  - **Initial oxidation and/or hydrolysis to make low molecular weight functionalized oligomers and organic acids, followed by:**
  - **Microbiological digestion to make lipids and other high-value chemical products.**
- **Products are aimed at replacing petrochemical or palm oil compounds in emulsifiers, cleaners and personal care formulations**
- **Current work is aimed at post-consumer film and mixed rigid plastics from MRFs**
- **Problems to be solved include unwanted chemical additives in the plastics and contamination from other trash attached to the plastics. Working on improved microorganisms to alleviate this**
- **Eventual goal is to make this work for multilayer systems**

DEVELOPMENT OF SINGLE POLYMER BARRIER MATERIALS

- **Mechanically recyclable barrier and pouch packaging using single polymer material approved for How2Recycle store drop-off recycling programs developed through collaboration with the Sustainable Packaging Coalition**
- **Cost effective replacement for non-mechanically recyclable PET/PE laminates processable on conventional conversion and packaging equipment**
- **Dow "RecycleReady" technology using 100% "Innate" single-site polyethylene pouch materials. More puncture-resistant than PET/PE and barrier can be incorporated with an EVOH layer**
- **Nova Chemicals Surpass Octene LLDPE resins with improved sealability. 50% increase in moisture and oxygen barrier compared with HDPE and higher stiffness**


DOW
NEW!
100% PE
Stand Up Pouch
100% Polyethylene
83% less plastic*
*Study available under consultation
Differentiation, savings and less waste
200ml

Dow Chemical Innate Polyethylene Polymers Versus PET/PE Structures

Film Comparison, PET/PE versus PE SUP *

	PE SUP	PET/PE
Modulus (stiffness)	+	++
Tear resistance	++	+
Impact resistance	+	++
Puncture resistance	++	+
Moisture barrier	++	+
Oxygen barrier	+	++
Upper temperature limit	+	++

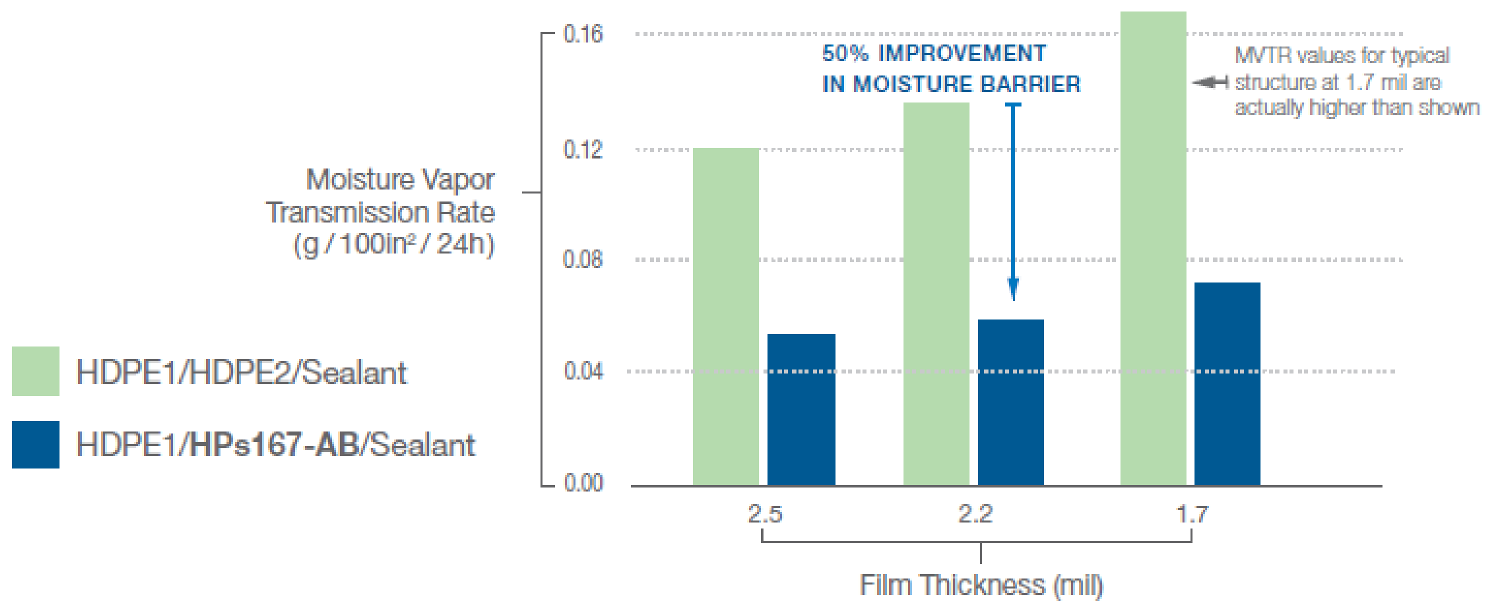
+ = Good Performance ++ = Preferred Performance
Films used same PE product; films tested at identical thickness

Source: Dow

Performance Comparison for Novachem SURPASS HPs167-AB Resin.

PERFORMANCE COMPARISON

Achieve up to 50% moisture barrier performance improvement with SURPASS HPs167-AB resin:



HDPE FILM STRUCTURE	Skin Layer: 15%	Core Layer: 70%	Sealant Layer: 15%

MOISTURE VAPOR TRANSMISSION RATE CO-EXTRUDED FILMS

Source: Nova

DEVELOPMENT OF BARRIER COATINGS AND ADHESIVES

- **Barrier coatings and adhesives can be extremely thin (a few nm) and not compromise mechanical recyclability while providing an impenetrable oxygen barrier.**

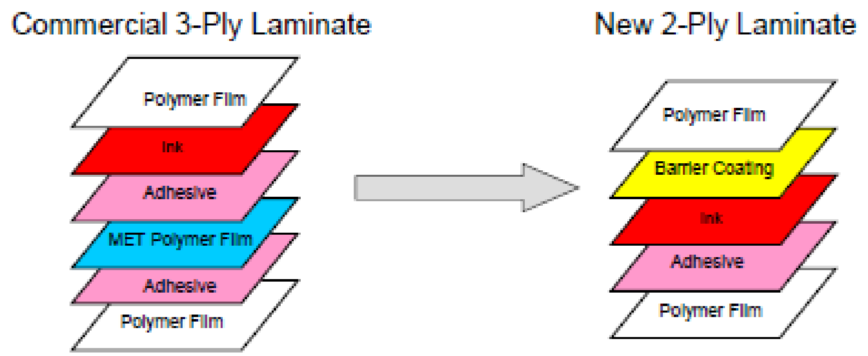
Examples are:

- **SiOx-, AlOx- and amorphous carbon-nanocoated polyolefins, polyesters and polyamides, e.g. Amcor “Ceramis” and Toppan GL**
- **Nanoclay-coated and acrylate-coated polymer films**

- **BUT there is still a problem of collection and sorting to separate and recycle them mechanically into base polymer. This may be no easier than using multilayer barrier materials which can be recovered to produce energy or fuels**
- **Also there still remains the problem of film contamination, particularly food waste, since it is hard to get clean postconsumer film for recycling**

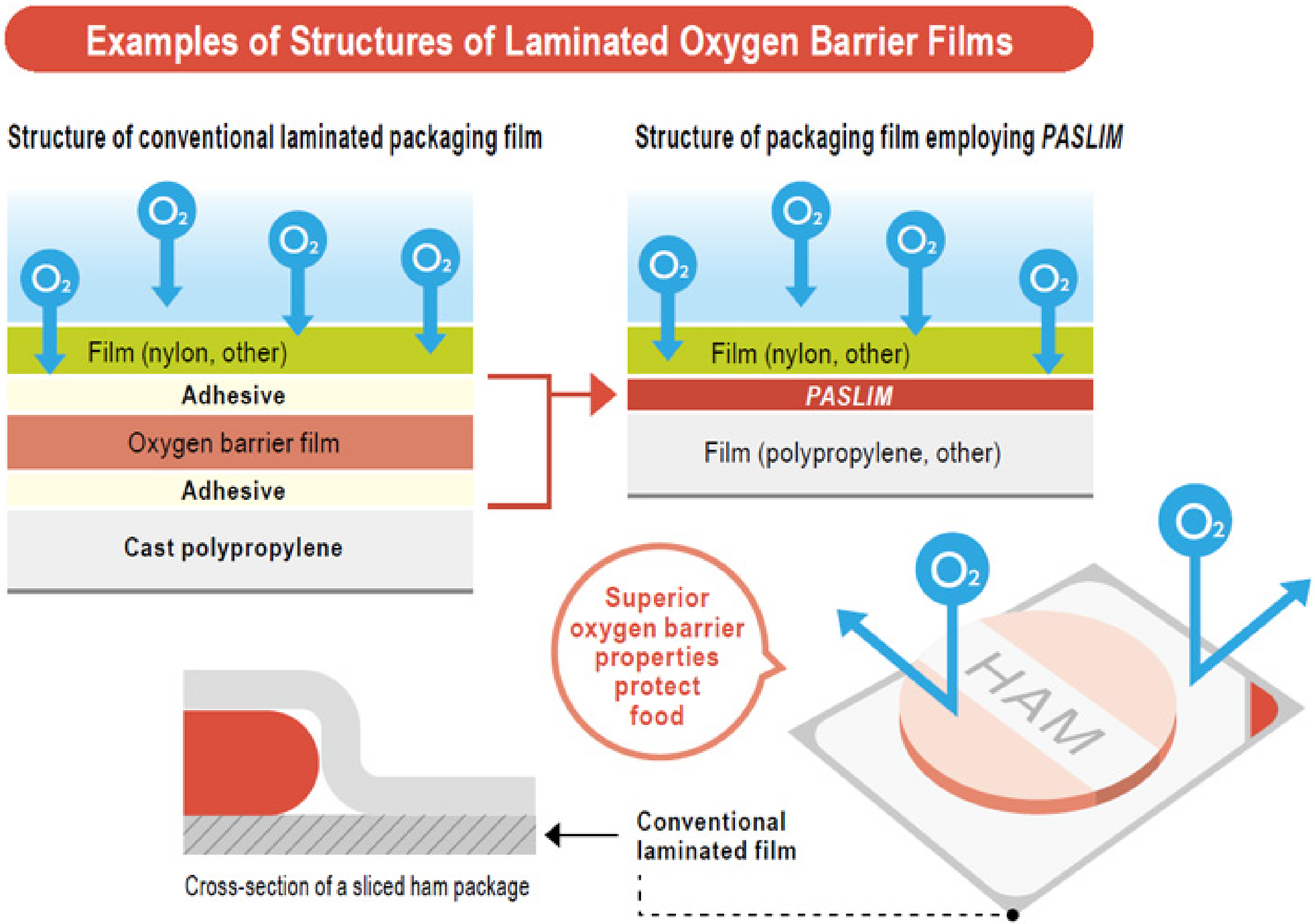
SUNBAR OXYGEN BARRIER COATING

Oxygen Barrier Lightweighting Example



Souce: Sun Chemical

DIC PASLIM BARRIER ADHESIVE

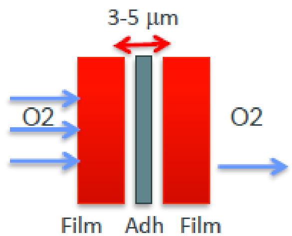


Souce: DIC

Dow Chemical "Innate" Polyethylene Polymers Versus PET/PE Structures.

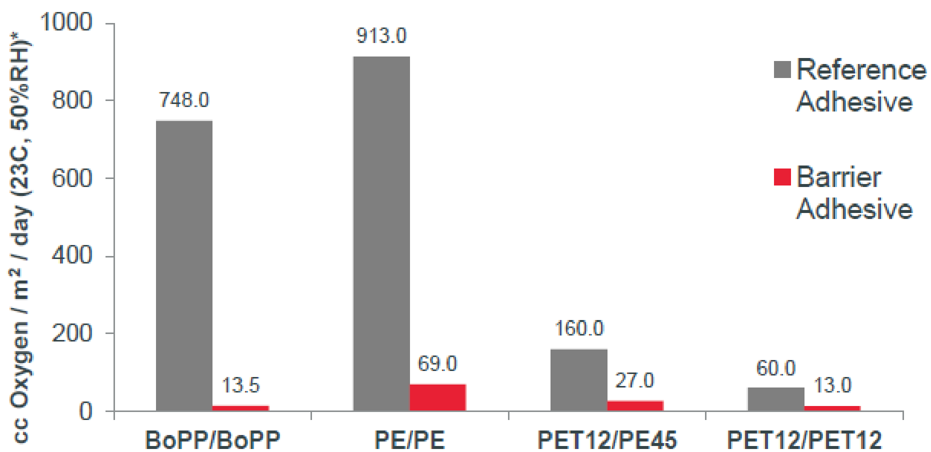
RECYCLEREADY™

technology for store drop-off recycling by DOW



Barrier Adhesive Technology:

PET performance in all-PE film



Souce: Dow

COMPATIBILIZER DEVELOPMENT TO AID RECYCLING OF FLEXIBLE PACKAGING

- **Molecules with different functional groups to aid recovery of incompatible polymers in multilayer packaging film systems and mixed plastics**
- **Dow Chemical "Retain" Technology for PE/EVOH/PA barrier systems as part of "RecycleReady" Program. Enables production of barrier packages and pouches that can be recycled in a PE recycling stream.**

  Upon recycling of multilayer film, the compatibilizer disperses the EVOH or PA in the PE in small domains so that the PE is still transparent and can be reused although the EVOH is no longer present as a barrier layer

- **DuPont functionalized copolymer compatibilizers for PP/PE (Entira), PET/LDPE, PA/PE, PE/EVOH and other combinations.**

DUPONT COMPATIBILIZER TECHNOLOGY

Major Fraction \ Minor Fraction	PET	H/LDPE	PP	PVC	PS	ABS	PA	EVOH
PET		Elvaloy®, Fusabond®	Elvaloy®, Fusabond®				Elvaloy®	
H/LDPE	Elvaloy®, Fusabond®		Entira™ EP	Elvaloy® AC, Elvaloy®	Elvaloy® AC		Fusabond®	Fusabond®
PP	Elvaloy®, Fusabond®	Entira™ EP			Elvaloy® AC		Fusabond®	Fusabond®
PVC		Elvaloy® AC, Elvaloy®	Elvaloy® AC, Elvaloy®					
PS		Elvaloy® AC	Elvaloy® AC			Elvaloy® AC		Fusabond®
ABS		Elvaloy® AC	Elvaloy® AC		Elvaloy® AC			

Elvaloy® AC	Acrylic copolymer
Elvaloy®	Functional terpolymer
Fusabond®	Grafted copolymer
Surlyn®	Ionomer
Entira™ EP	Modified copolymer

OTHER DEVELOPMENTS TO AID RECYCLING OF FLEXIBLE PACKAGING

- **Non-stick surfaces**
- **These provide permanently wet and slippery surface to solve problem of surface contamination of packaging films, particularly contamination with food waste, e.g. LiquiGlide (MIT)**
- **Allows viscous liquids to slide effortlessly with no residual surface contamination; e.g. ketchup, honey, peanut butter, yoghurt, mayonnaise, mustard, salad dressing, toothpaste, adhesives, oil**

- **Anaerobically digestible, compostable and biodegradable plastics**
- **Alternative disposal streams leading to energy (AD biogas) and fertilizer**
- **Still have difficult problem of collection, sorting and separation from other plastics**

SUMMARY

- Flexible packaging, particularly multilayer barrier and pouch packaging, has significant advantages and is expanding rapidly
- Flexible packaging is ecologically advantageous due to low use of materials and energy, low carbon footprint and GHG emissions, and reduction in food waste
- However, it is still under attack by environmental groups because of difficulty of economic mechanical recycling, so that it presently mostly ends up in landfill
- The food, packaging and recycling industries are responding strongly to this attack with programs to educate consumers on sustainability advantages and to obviate landfilling by developing:
  - New materials and package designs
  - Improved collection, identification, marking and sorting methods
  - Economic new recycling and recovery methods, including delamination and dissolution processes and conversion to energy, fuel and downstream chemicals
- Implementation of these various potential routes will depend on local and national logistical, economic, social and political situations, not just technological factors

THANK YOU FOR YOUR INTEREST

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Specialist consultancy services in:

- **Sustainable packaging and recycling processes**
- **Water-soluble, biodegradable and compostable plastics**
- **Biobased and renewably-sourced plastics**
- **Materials and formulation development and selection**
- **Market and applications development and analysis**

Member of the Plastics Consultancy Network and the Chemical Consultants Network