



# ADVANCED RECYCLING AND CURRENT TRENDS ON FEEDSTOCK STRATEGIES

NERC WEBINAR

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Managing change  
in a resource-  
constrained world.



ORGANICS  
MANAGEMENT



WASTE  
RECOVERY



GLOBAL CORPORATE  
SUSTAINABILITY

since 1986

# AGENDA

Technology overview

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How feedstock requirement vary by technology

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What's happening in the industry

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Commercial outlook

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Environmental Performance

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Feedstock opportunities and strategies

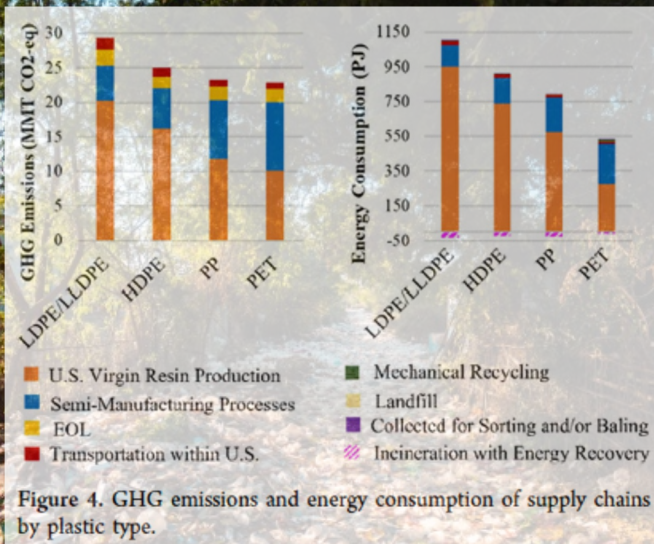
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Insights on feedstock strategies

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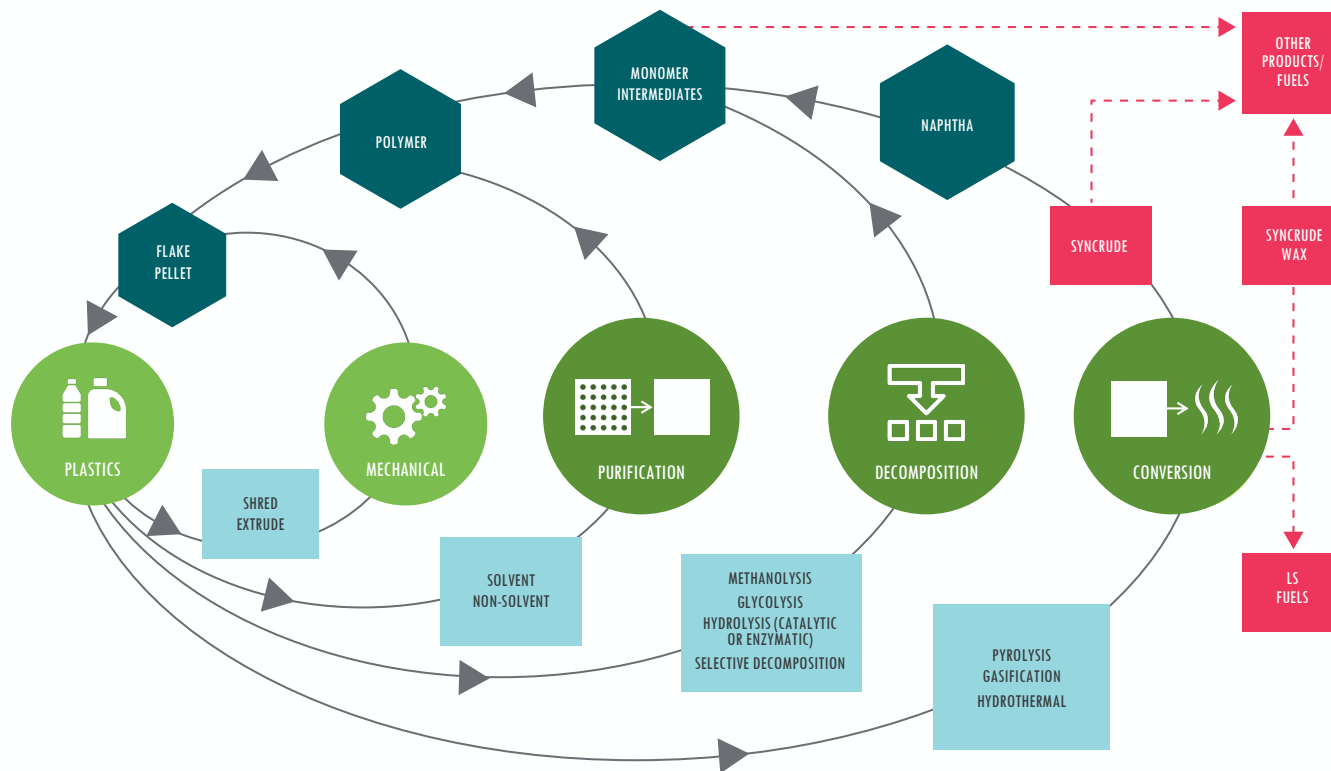
Takeaways

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Source: Utkarsh S. Chaudhari, Anne T. Johnson, Barbara K. Reck, Robert M. Handler, Vicki S. Thompson, Damon S. Hanley, Wendy Young, David Watkins, and David Shonnard. *Material Flow Analysis and Life Cycle Assessment of Polyethylene Terephthalate and Polyolefin Plastics Supply Chains in the United States*. *ACS Sustainable Chemistry & Engineering* **2022** 10 (39), 13145-13156. DOI: 10.1021/acssuschemeng.2c04004

# ADVANCED RECYCLING TECHNOLOGIES — AN EMERGING TOOL TO ADDRESS PLASTIC WASTE



- Diverse suite of technologies. Few commercially operating facilities.
- Targeting hard-to-recycle plastics and forms that are technically or economically challenging in mechanical systems.
- Upcycle low value and colored plastics with properties comparable or like virgin – films, PP, etc.
- Some technologies target specific resins others take mixed plastics.

# DIFFERENT TECHNOLOGIES, DIFFERENT FEEDSTOCKS, DIFFERENT QUALITY THRESHOLDS

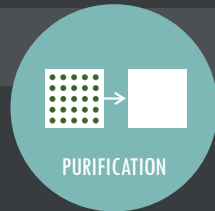


MECHANICAL



**PRODUCT: FLAKE/PELLET**

- Readily recyclable rigid containers that are easy to identify and sort. PP is emerging but challenging due to diversity of formats and color.
- Postconsumer
- Single resin PET, HDPE, PP
- Purchase sorted bales from MRFs
- Cost of single resin postconsumer bales is generally not competitively priced for ART technologies without subsidy

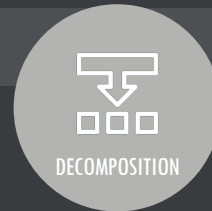


PURIFICATION



**PRODUCT: PELLET**

- Non-bottle rigids, cups, trays, microwaveable trays, non-wovens, carpeting, crates, toys, multi-laminate films
- Postconsumer/Postcommercial/Postindustrial
- Single resin PP or PE/PP films
- Purchasing low cost MRF bales and sourcing from non-MRF source
- Examples: PureCycle, APK



DECOMPOSITION



**PRODUCT: MONOMERS OR INTERMEDIATES**

- Non-bottle rigids, trays, cups, clamshells, films, textiles, carpeting
- Postconsumer/Postcommercial/Postindustrial
- Single resin PET, PA6 or PS/EPS for monomer recovery
- Typically sourced directly except with EPR.
- Examples: Eastman (PET), Aquafil (Nylon), GreenMantra (POs), Agilyx (EPS/PS)



CONVERSION



**PRODUCT: SYNGAS, SYNCRUDE, PYROIL**

- Not yet recycled mixed POs and forms that are hard to collect. Films, soft plastics, seasonal films, off spec, pipe, tanks, motor oil containers, electronics etc.
- Postcommercial/Postindustrial/Postconsumer
- Mixed PEs/PP/PS.
- Directly develop supply networks. Do not purchase sorted material from MRFs.
- Examples: Brightmark, Nexus Circular, ExxonMobil

## RECENT ANNOUNCEMENTS

### **“Amcor signs PCR offtake deal with ExxonMobil” 12.22**

**Orlando Magic Advance Sustainability Efforts with PureCycle's PureZero™ Program 11.22**

**Dow and Nexus Circular Announce Plans to Build New Advanced Recycling Facility in Dallas, TX, Expediting Circular Plastics Production in USA 07.22**

BRASKEM EXTENDS RELATIONSHIP WITH NEXUS CIRCULAR THROUGH MOU FOR COMMERCIAL OFF-TAKE OF CIRCULAR PLASTIC FEEDSTOCKS FROM NEW ADVANCED RECYCLING FACILITY 07.22

**WM and Dow Rollout First Major Residential Plastic Film Recycling Program in the U.S. 11.22**

WM to Acquire Controlling Interest in Avangard Innovative's U.S. Business 09.22

Honeywell, Avangard to Build New Advanced Recycling Plant in Texas 02.22

**Dow strikes agreement with Avangard to further circular economy goals 01.20**

*As it looks to build its third chemical recycling facility in the U.S., Eastman is forging partnerships with PepsiCo and P&G to receive its processed PET 11.22*

# COMMERCIAL OUTLOOK

- Level of investment is much greater than mechanical recycling
- Various business models from fuel to plastics with presumed premium from postconsumer material
- Integration models emerging from feedstock to products
- Economics still unproven but likely to start shaking out

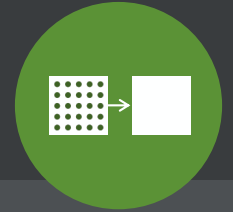
## North American Commercial Leaders:

- Enerkem\* (gasification)
- ExxonMobil (Gasification?)
- New Hope Energy (pyrolysis)
- Brightmark (pyrolysis)
- Nexus Circular (pyrolysis)
- Purecycle (purification)
- Agilyx/Regenyx (pyrolysis)
- GreenMantra (selective decomposition)

All have at least one commercial facility operating at end of 2022 with more facilities planned or under construction.

**MORE THAN 12 PENDING FACILITIES**

# PURIFICATION PROCESSES



- Chemical refining process that uses selective chemistries or solvents under specific conditions to remove color, additives, fillers, etc. Often referred to as solvolysis.
- Does not break polymer bonds so that physical properties of plastics that go into system are comparable to what comes out.
- Received LNO for postconsumer material and letter of approval for PIR
- Can address non-traditional materials like non-wovens
- Investing in 3 PRFS. Targeting 3-7 bales, event plastics, carpeting, non-wovens, etc.



## PURECYCLE TECHNOLOGIES

Feedstock - PP packaging, carpet, non-wovens







Product - Virgin-like food grade PP

Sites – Ironton, OH; Augusta, GA

PRFs – FL, GA, PA



# FACTORS THAT IMPACT THE ECONOMICS OF ADVANCED RECYCLING

FEEDSTOCK		TRANSFORMATION		OUTPUT	
					
TYPE	SOURCE	PRE-PROCESSING	REACTION	POST-PROCESSING	PRODUCTION
Post Consumer (PC) Institutional Commercial Industrial (ICI)	MRFs Reclaimers Manufacturers Retailers Collectors	Sorting Shredding Cleaning	Temperature Pressure Chemicals Catalyst	Distillation Refining Polymerizing Pelletizing	Plastics Fuels Alt Products
<b>CONSIDERATIONS</b> Availability   Reliability Quality   Cost		<b>CONSIDERATIONS</b> Capex   Opex   Capacity Yield   Throughput Energy Source		<b>CONSIDERATIONS</b> Need for Offtake Partner Quality spec   End market Ability to charge premium	

**ENVIRONMENTAL CONSIDERATIONS:** Resource Consumption, Air/Water/Waste Emissions, Toxicity

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# ENVIRONMENTAL PERFORMANCE

- Brightmark's peer reviewed LCA indicates a 39% to 139% reduction in carbon emissions and an 82% energy reduction compared to virgin fuel production. Benefit is directly correlated to EOL management.
- Purecycle LCA indicates 35% lower carbon emissions and 79% less energy than virgin PP production.
- Mechanically recycled olefins have about a 70% reduction in carbon emissions and a 55% reduction in energy used compared to virgin resin without the same quality characteristics – Source: APR/Franklin Associates
- Pyrolysis likened to incineration which is incorrect. It is not a combustion process and has different emissions and products
- Evaluations of current operations processing plastics do not support claims of excessive hazardous waste and toxic emissions

## For information on Environmental Performance:

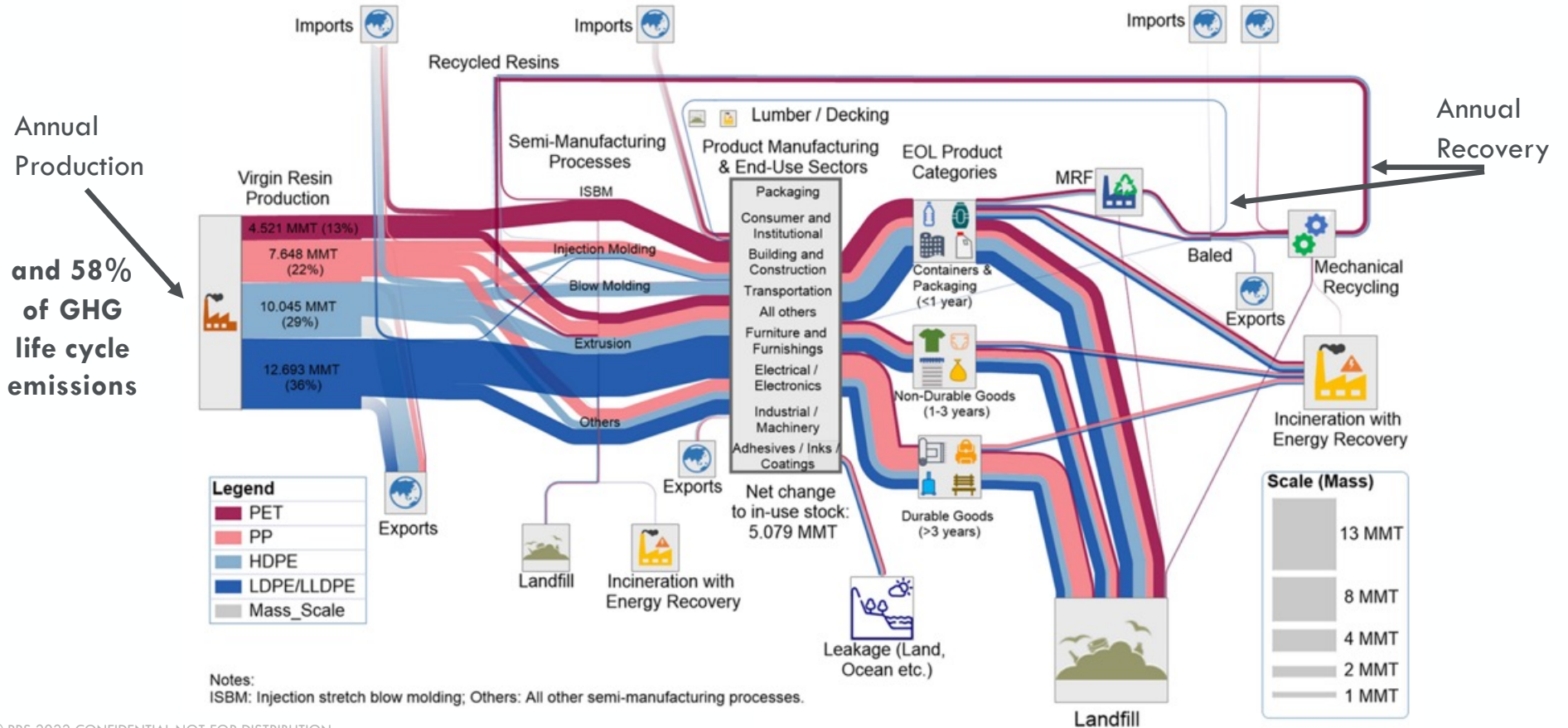
- High level directional comparisons across technologies see: [Closed Loop Partners](#)
- Comparison of pyrolysis to other industries see: [GoodCompany](#)



## FEEDSTOCK OPPORTUNITIES & STRATEGIES

# BASELINE MATERIAL FLOW SYSTEM FOR PET AND POLYOLEFIN PLASTICS IN THE US

Source: Utkarsh S. Chaudhari, Anne T. Johnson, Barbara K. Reck, Robert M. Handler, Vicki S. Thompson, Damon S. Hartley, Wendy Young, David Watkins, and David Shonnard. *Material Flow Analysis and Life Cycle Assessment of Polyethylene Terephthalate and Polyolefin Plastics Supply Chains in the United States*. *ACS Sustainable Chemistry & Engineering* 2022 10 (39), 13145-13155 DOI: 10.1021/acssuschemeng.2c04004



# COMMON CHALLENGES FOR ADVANCED RECYCLING TECHNOLOGIES — DEVELOPED MARKETS

- Municipal collection programs are typically limited to forms with known value—hard-to-recycle and low value plastics are not collected.
- Economics of postconsumer film and flexibles collection are challenging outside of EPR systems.
- Film and flexibles represent a huge volume of packaging but with little-to-no municipal collection infrastructure outside of the EU. and other select markets.
- In US, nationally low participation has led to supply constraints to support solutions that are scaled to production volumes.
- Current collection systems are not scaled to use of consumer packaging and other plastic products so significant volumes are missed.



# ISSUES SOURCING POST-INDUSTRIAL AND POST-COMMERCIAL PLASTICS

- Well developed systems but not well understood or volumes documented.
- PIR diverse quality from very clean to very mixed.
- Clean PIR material is valued by reclaimers and durable good manufacturers.
- Post-commercial material is also valued. High volumes with reliable quality and ranges from clean to dirty.
- Business to business transactions. Not typically tracked or reported.
- For many post use nondurable and durable forms there are rarely collection and reverse logistic systems in place (i.e., ag films, containers, drainage pipe, etc).





# INSIGHTS ON FEEDSTOCK STRATEGIES

Image: Thai, Sherrie. "Purple Polyester Fabric." Flickr, 22 July 2010.



## TRENDS AND STRATEGIES

- Feedstock availability and quality have emerged as key challenges for all advanced recycling technologies and pose a hurdle to effective scaling of technologies.
- Targeting previously uncollected, plastic residuals or low-cost material that MRFs receive but do not sort as well as material direct from generators.
- Avoiding competition with feedstocks targeted by mechanical recyclers.
- Lack of reverse logistics to collect and aggregate plastics outside of municipal systems or less than truckloads is a significant challenge and a hurdle to growing a meaningful circular economy for plastics and packaging.
- Developing PRF infrastructure to sort mixed plastic bales and other sources of supply.



# EMERGING PRF MARKET

## IRG PRF IN ERIE, PA

- To be opened ~2023
- Expected capacity of 550 Mlbs of mixed plastics

## CYCLYX PRF IN HOUSTON, TX – REGIONAL APPROACH

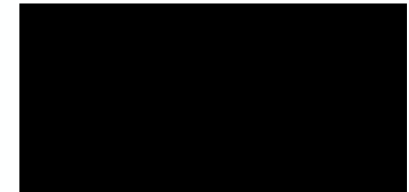
- To be opened ~2024
- Expected capacity of 130M lbs

## PURECYCLE PRF IN WINTER GARDEN, FL

- Currently commissioning 150 Mlbs
- 2 more under construction [GA, PA] 500M lbs
- To sort mixed plastics and event plastics and process PP

## REPUBLIC SERVICES POLYMER CENTER IN LAS VEGAS, NV

- To be opened ~2023; first of 4 in planning
- PET line with separate olefin line





## TRENDS AND STRATEGIES

- Movement to lock in ownership of waste plastics through partnership and JVs. (e.g., WM/Avangard/Dow)
- Integrating pre-processing of feedstocks into operations (e.g., Brightmark) or forming partnerships to access pre-processed materials (e.g., Cyclyx)
- Developing specific feedstock networks for individual processing sites using long-term supply agreements.
- Bootstrapping process of identifying regional source opportunities (e.g., municipal, MRF, or commercial, industrial) and negotiating supply agreements.
- Eventually expect a bale specs may emerge directed to different types of ART (i.e., PET thermoforms, dirty films).

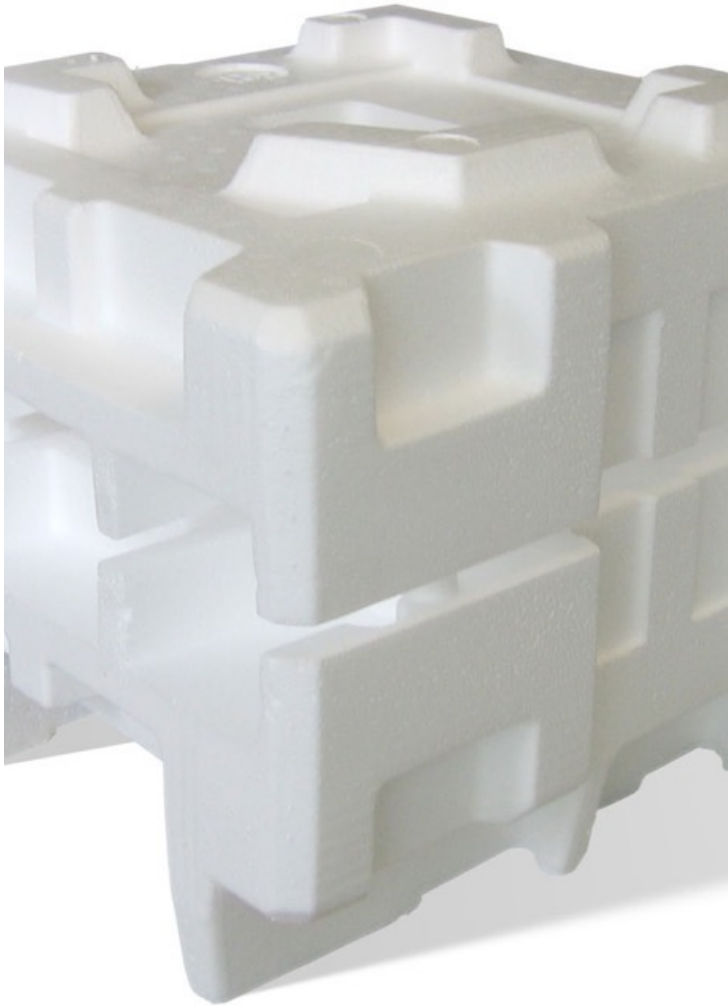


Image: User:Acidx. "Polystyrene packaging material." Wikimedia Commons.

## CHALLENGES IN NORTH AMERICA

- NGO's have taken a strong negative stance on "chemical recycling" likening it to incineration with problematic emissions and wastes.
- Significant level of misinformation about some technologies and emissions that are not based on current technology, operational performance or feedstock mix (i.e., pyrolysis of tires vs mixed plastic)
- Operators of ART and mechanical processing are both experiencing not-in-my-backyard (NIMBY) when trying to locate facilities.
- Certain categories of "chemical recycling" are not likely to be considered recycling in some states.

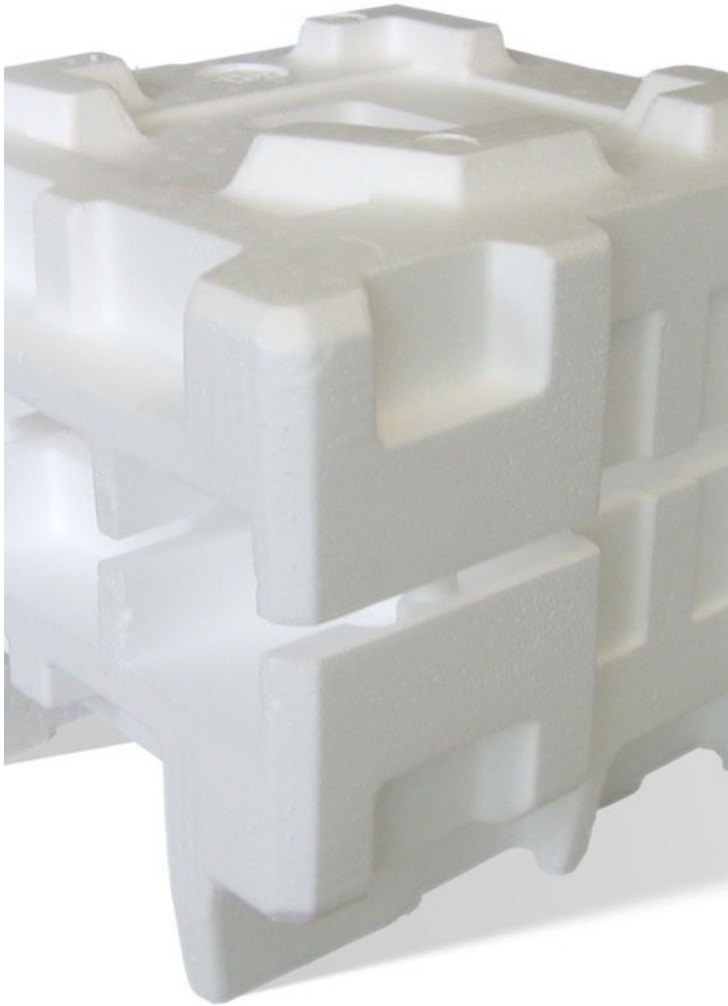


Image: User:Acdx. "Polystyrene packaging material." Wikimedia Commons.

## TAKEAWAYS

- Today ART feedstock strategy development is an immense undertaking and do not benefit from shared collection or sorting infrastructure
- Immense pool of potential plastic. To unlock need better data on sources of supply outside of municipal system and reverse logistics systems.
- Should not be a competitive issue. Intentional coordination and collaboration across stakeholders is needed if a circular economy for plastic is to become a reality
- ART Industry needs to perform, show the data and then educate
- Outside of ART there are no technologies that operate at a large enough scale to address and reduce reliance on virgin resin



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