Michigan Recycling Coalition
40th Recycling and Organics Conference

Managing Monomers in Michigan:
An Outside Perspective on Plastics Recycling

Vectorstock.com

Concurrent sessions
Thursday, May 12, 2022
10:10 am to 11:00 pm

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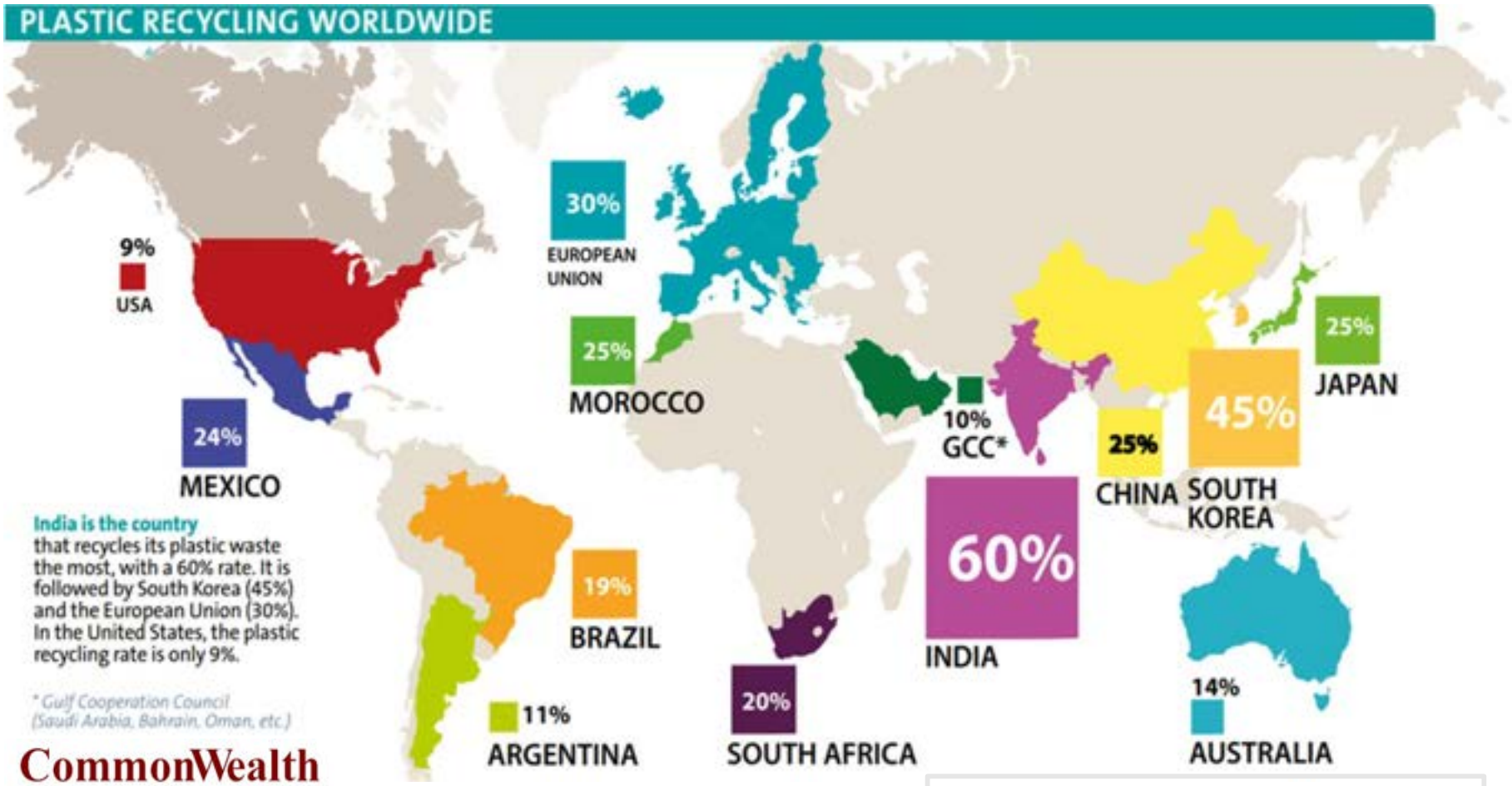
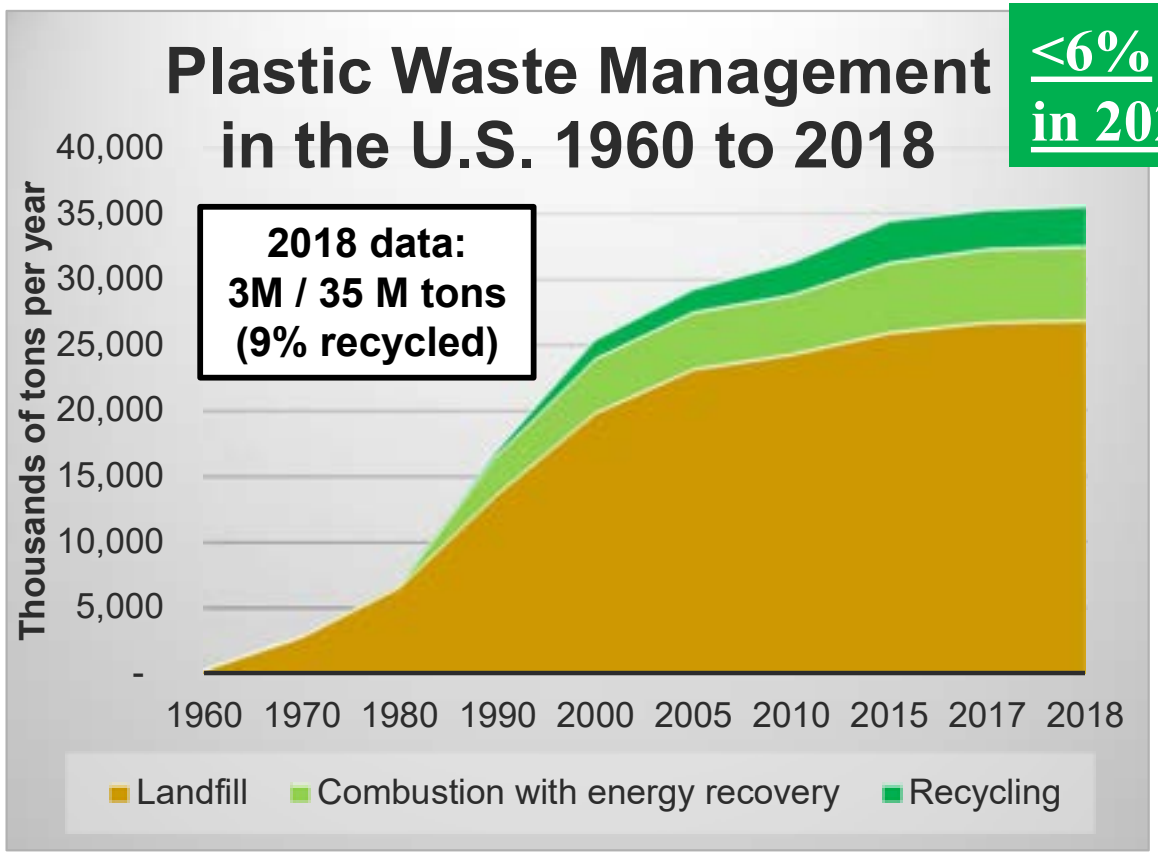
Plastic recycling rates around the world

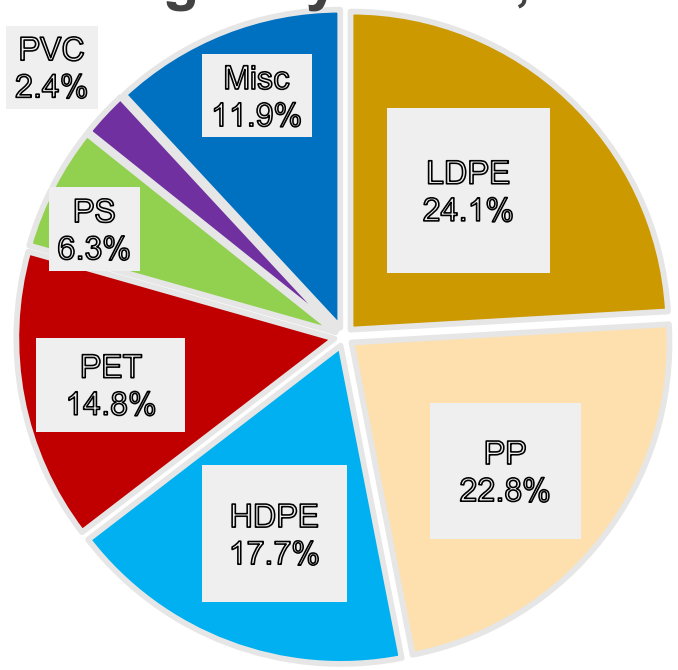


Source: United Nations, 2018

Plastic waste pre-Covid: US tons and resins



<6% in 2021



USEPA data. Exports not shown

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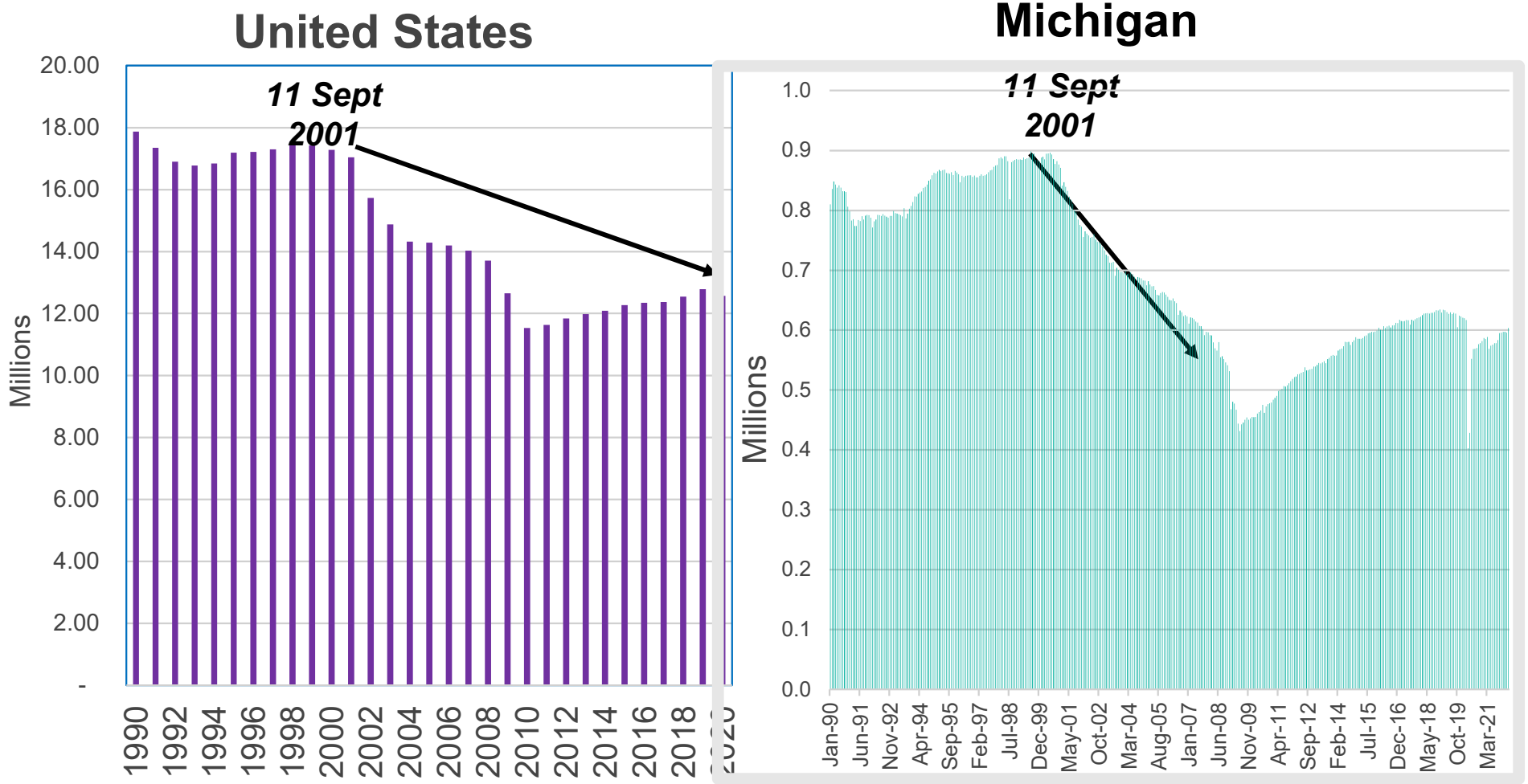
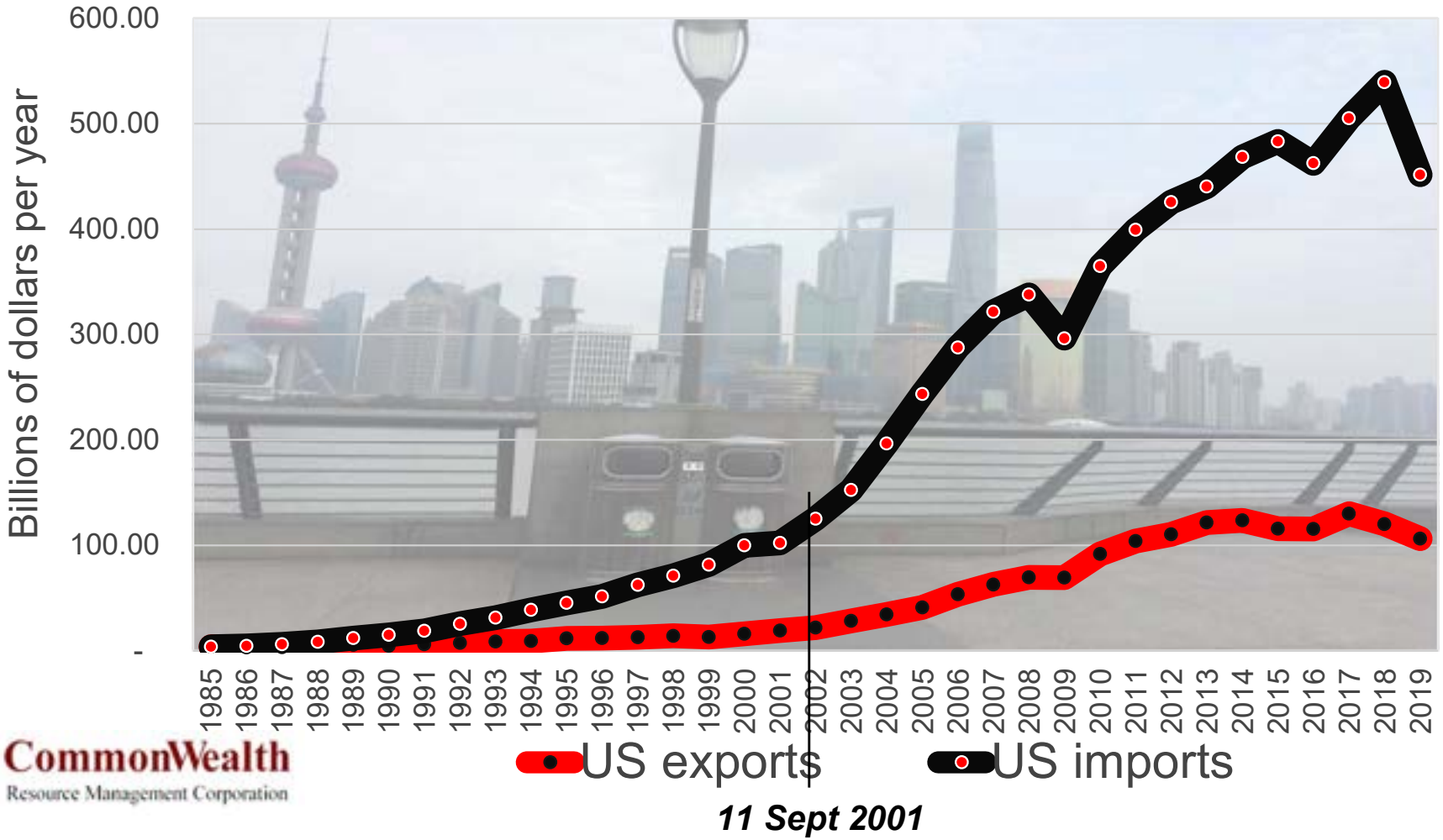
Manufacturing Employment, 1990 to 2020

Data from FRED – Federal Reserve Employment Database.



U.S China trade, 1985 to 2020

Data from the U.S. Department of Commerce Photo by G Aronson



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China starts its own recycling programs

Waste plastic to synthetic diesel,
Tinghu District, City of Yancheng,
Jiangsu Province, Republic of China

All photos by G Aronson

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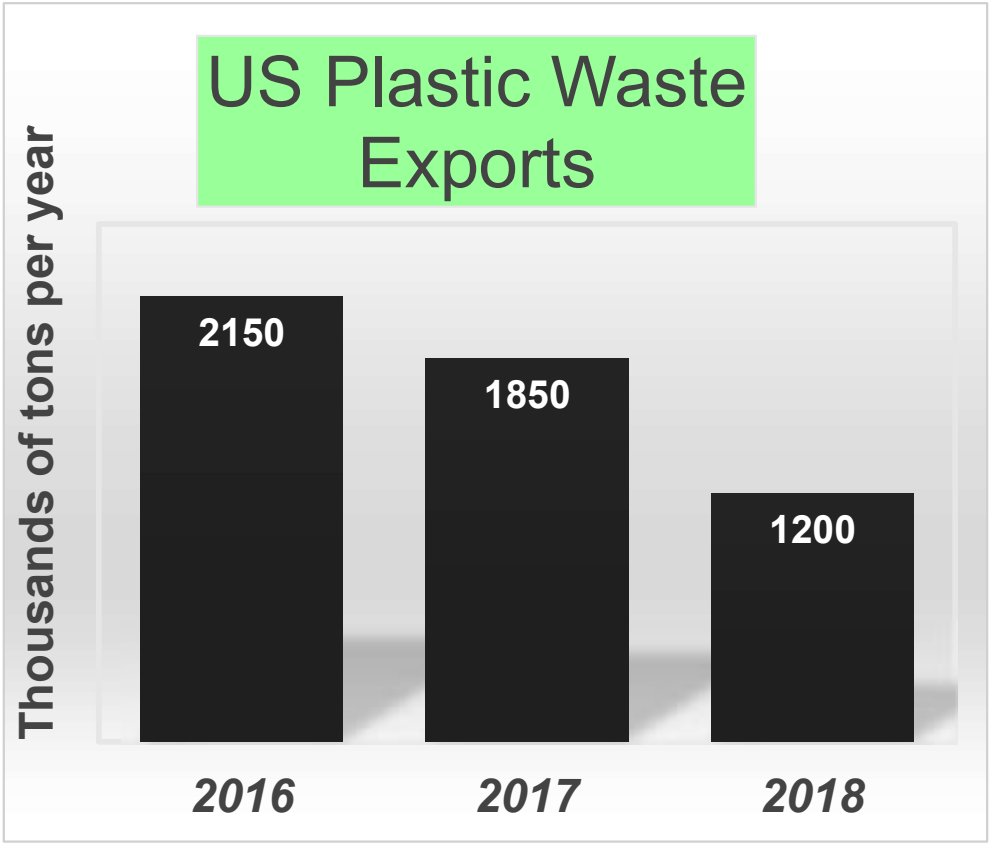
Post-consumer plastic global markets, 2017-2021

2013	China's "**Green Fence**" limits all scrap contamination, including plastics
2018	China's "**National Sword**" bans mixed plastic waste imports, limits contamination to 0.5%
2018	Other Asian countries limit imports Chinese plastics companies enter US market
2019	MRFs **stockpile plastics, reduce collection** China and US announce **tariff increases**
Result	Global imbalance of waste plastic supply and demand

Plastics recycling: export markets, 2017-2018

China bans mixed plastic imports on January 1, 2018
limits contamination to 0.5% as of March 1, 2018



	2017	2018
China	611	60
Hong Kong	407	132
Vietnam	148	84
India	148	144
Malaysia	130	228
Mexico	56	48
Indonesia	37	36
Taiwan	37	60
Thailand	37	120
Other	93	132
	1850	1200

Data in thousands of tons per year

Plastic waste becomes a *GLOBAL CRISIS*

Ocean dumping, climate change impacts

New restrictions on waste exports in trade

Basel Convention, plastic waste amendments, 2021

- Plastic waste exports require notice and consent
- 187 countries sign; the US has not yet signed
- US waste plastic exports are now limited to
  - Pre-sorted clean uncontaminated materials; or
  - Bilateral agreements with notice and consent (Canada, Mexico, OECD)

In crisis there is opportunity!

- **Crisis: imbalance of waste plastic supply/demand**
- **Public response: reduce use of single-use plastics**
- **Industry response:** add plastics recycling capacity
  - Increased interest in ESG investments
  - New corporate carbon footprint reduction goals
  - Domestic sources improve supply chains
  - Recycled resins depend less on oil markets

U.S. Plastics Pact Unveils National Strategy to Achieve 2025 Circular Economy Goals. *June 15th, 2021*

1. Eliminate problematic or unnecessary packaging.
2. Make all plastic packaging reusable, recyclable, or compostable.
3. Recycle or compost 50% of plastic packaging.
4. Achieve average for plastic packaging of 30% recycled or responsibly-sourced bio-based content

https://usplasticspact.org/

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Corporate Shareholder Resolution Votes

amazon Vote May 25 on report to reduce plastics use by at least one-third

ExxonMobil Vote on May 25 on report on financial effects of reduced demand for virgin plastic

McDonald's Vote May 26 on plan to reduce plastic use

Meanwhile, back in Michigan:

- Demand for recycled feedstock exceeds supply
- Low-cost landfills
- No reliance on China

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Plastics recycling in Michigan: successes

Bottle Bill and bottle-to-bottle recycling

Pre-consumer recycling by manufacturers

MRFs and drop-off/TS locations for post-consumer waste

- 520,000 tpy MRF capacity (Gap Analysis 2021 Update w. 3 new MRFs)
- 58% HHs have curbside service;17.5% more have drop-off access

Market outlets within 200 miles of collection!

Film collection programs

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Plastics recycling in Michigan: challenges

Low post-consumer recycling

- 18% Michigan recycling rate in 2019 vs. 32% US recycling rate in 2021 per USEPA
- Remote areas are under-served
- *Critics say* Michigan under-collects plastic waste

Emphasis on high-quality plastic collection

- Limits what is accepted
- Residuals are rejected

Pending competition for feedstock

- National take-back networks (Trex)
- New mega-facilities in northern Indiana
- Brightmark in Ashley, IN; Fulcrum Bioenergy n Gary, IN

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Plastics recycling in Michigan: coming changes!

New EGLE goal – 45% recycling rate (vs. USEPA 50% by 2030)
Scale-up challenge: need **more**

- Collection
- Processing
- End markets
- Program investment

Scale-up challenge: need **less**

- Limits on what is accepted (e.g., 3-7 plastics)
- Process residuals

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Michigan Recycling Coalition: 40th Recycling and Organics Conference
Managing Monomers in Michigan
12 May 2022

Appeared in the Boston Globe on 8 August 2021.
Used by permission of the cartoonist.
Thank you Alex!

1. **Could local markets accept major increases in supply?**
2. **Will materials recycled in Michigan stay local or be affected by new large-scale facilities?**
3. **How important will quality be? Will the collection method matter?**

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Always start with waste reduction!

Reduce use of or ban single-use plastics such as shopping bags, water bottles, straws, etc.

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Revisit Oscar's question

Q: "If we could collect all the plastic in Michigan, what would we do with it?"

A. Mechanical and thermal recycling

- **Already done well in Michigan !!!**
- **LET'S DO MORE OF IT!**

Mechanical recycling

Feedstock must be clean

Often less sensitive to resin type

Michigan options

- End-users – small-scale low-tech facilities
- Traders/processors – supply chain

Facilities with large wasteshed areas

- Fayetteville, NC (Clear Path) –140,000 tpy PET

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Thermal recycling

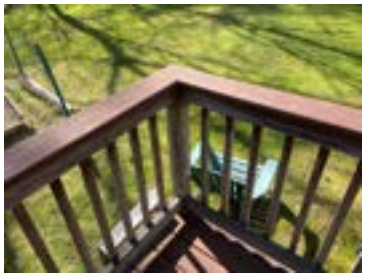
Flake, melt, remold and harden

Michigan options

- Clean Tech: bottles to bottles
- Cascade Engineering: pallets, eco-carts, etc.
- Petoskey: plastic waste to plastic bags
- Traders/processors – supply chain

National facilities – large wasteshed areas

- Winchester, VA - Trex decking from film
- Reidsville, NC (Envision Plastics) food-grade HDPE from ocean-bound plastics



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Revisit Oscar's question again

Q: "If we could collect all the plastic in Michigan, what would we do with it?"

What if more mechanical and thermal recycling aren't enough? What else can we do?

A: Let's take a deeper look

Plastics #1 - #7: the popular view

1 PET	02 PE-HD	03 PVC	04 PE-LD	05 PP	06 PS	07 O
Polyethylene terephthalate	Polyethylene (high density)	Polyvinyl chloride	Polyethylene (low density)	Polypropylene	Polystyrene	Bisphenol A and others
PET is commonly used in commercially sold water bottles, soft drink bottles, sports drink bottles, and condiment bottles.	HDPE is commonly used in milk and juice bottles, detergent bottles, shampoo bottles, grocery bags, and cereal box liners.	PVC can be flexible or rigid, and is used for plumbing pipes, clear food packaging, shrink wrap, plastic children's toys, tablecloths, vinyl flooring, children's play mats, and blister packs (such as for medicines).	LDPE is used for dry cleaning bags, bread bags, newspaper bags, produce bags, and garbage bags, as well as "paper" milk cartons and hot/cold beverage cups.	PP is used to make yogurt containers, deli food containers, furniture, luggage and winter clothing insulation.	PS, also popularly known as Styrofoam, is used for cups, plates, take-out containers, supermarket meat trays, and packing peanuts.	Any plastic item not made from the above six plastics is lumped together as a #7 plastic. things like CD's baby bottles and headlight lens

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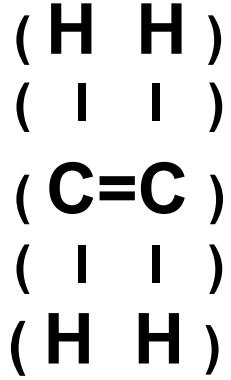
Plastics: atoms and monomers

Atoms **Carbon (C)** **Oxygen (O)**
Hydrogen (H) **Chlorine (Cl)**

Monomer



Example shown is ethylene monomer – C_2H_4

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Plastics: what is a polymer?

Atoms Carbon (C) Oxygen (O)
Hydrogen (H) Chlorine (Cl)

Polymers
(many monomers)

```
( H H )   ( H H )   ( H H )
( I  I )  ( I  I )  ( I  I )
( C--C) -- ( C--C ) -- ( C--C) -- etc.
( I  I )  ( I  I )  ( I  I )
( H H )   ( H  H )  ( H  H )
```

*Example shown is **poly**ethylene polymer – $(C_2H_4)n$*

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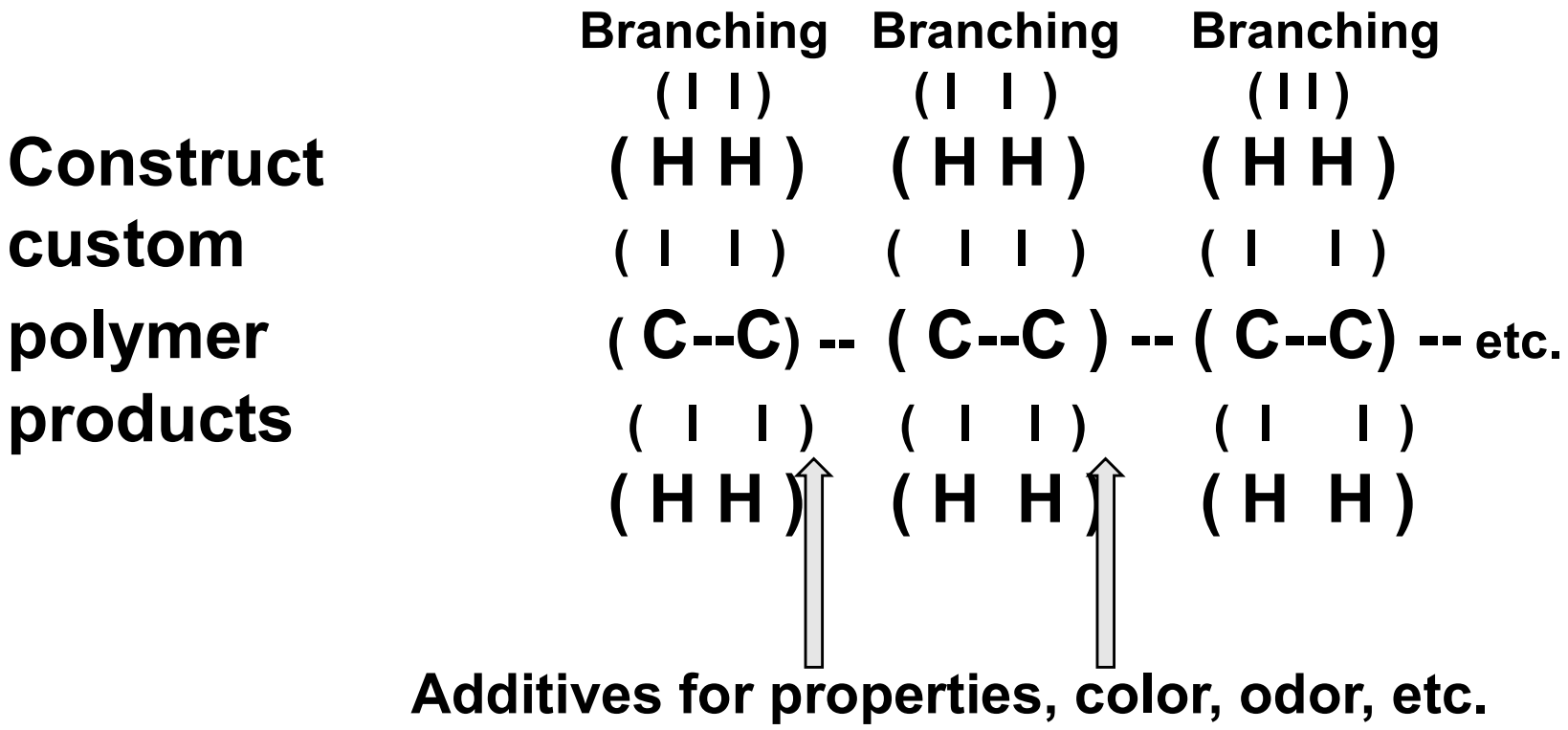
Plastic polymers can be constructed!



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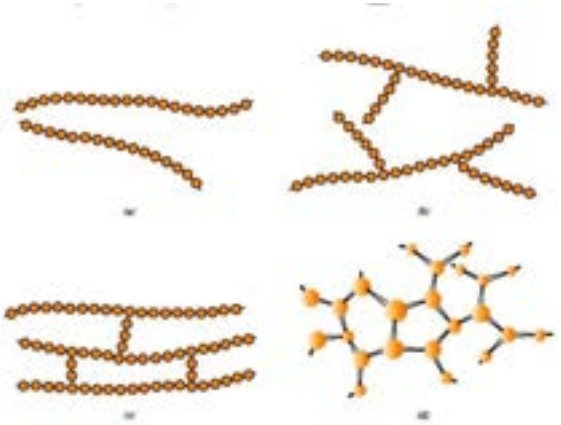
Plastic monomers #1-#7

Type	Monomer	Melt/freeze T	Comments
#1 PET	$C_{10}H_8O_4$	500 deg F	Oxygen in the monomer!
#2 HDPE	C_2H_4	270 deg F	Crystalline, rigid, not branched
#3 PVC	C_2H_3Cl	212+ deg F	Chlorine in the monomer
#4 LDPE	C_2H_4	230 deg F	Non-crystalline, flexible, branched
#5 PP	C_3H_6	320 deg F	Strong and stable
#6 PS	C_8H_8	800 deg F	Heat resistant; concerns with additive leaching
#7 Misc.	Many !	Wide range	Wide range of properties

Polymers can be very large molecules



Bowling balls and tires: one molecule each?

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Large molecules can get deconstructed!

Rack 'em up and break them apart!

Add:

heat,

pressure,

catalysts,

solvents,

reactants

syngas (C1 to C4).

liquid fuels (C5 to C17+)

and ***char***

to polymers in a reactor vessel without oxygen to yield

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Polymer deconstruction

is sometimes called depolymerization,
sometimes called "pyrolysis" or "gasification"
and sometimes treated as recycling -- either
"Chemical Recycling" or "Monomer Recycling"

Shred/clean waste plastics and remove contaminants
Feed reactor to convert to syngas
Burn syngas to make electricity
Recover pyro-oil and refine into liquid fuels or return to monomers
Make carbon black or biochar fertilizer

Alterra chemical recycling plant, Akron, OH

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Waste plastics to diesel by pyrolysis, Jiangsu Province, Republic of China

1. Feedstock pre-processing

2. Conversion in a reactor vessel with mixing, heat and a catalyst

All photos by G Aronson

3. Product distillation and refinement

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Chemical recycling – small-scale

Convert waste plastic to fuels

On-site applications (product/process residuals)

- Generate electricity on-site from local waste (steam or organic Rankine-cycle turbines)
- Make syngas for on-site process heat/CHP

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Chemical recycling – large-scale

Brightmark: pyrolysis/gasification of 1s through 7s to synthetic diesel fuel, naphtha blend stocks, food-grade wax

- 100,000 tpy new capacity, **Ashley, IN**, in start-up
- 400,000 tpy additional capacity by 2025

Fulcrum Bioenergy Centerpoint Biofuels Plant: convert 700,000 tpy MSW to 33 M gal/yr drop-in jet fuel

- Conversion plant proposed for **Gary, IN**
- MSW pre-processing MRFs in Chicago and along I-65

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Monomer recycling

PureCycle (Proctor & Gamble): replace PET/HDPE with PP

- 50,000 tpy new capacity, Ironton, OH by 4Q 2022
- 500,000 tpy new capacity, Augusta, GA. by 2025

Eastman Tritan™ Renew to produce monomer blend stock

- Full recycling of C-H monomers, 1-2 and 4-7
- 100,000 tpy new capacity, Kingsport, TN, by 2022

Alterra Energy, Akron,OH

- 60 tpd thermochemical liquefaction plant in operation

Chemical and monomer recycling

"The seven commercial-scale advanced recycling facilities, plus those leveraging existing chemical manufacturing to make virgin-quality plastics from used plastics, are just the beginning of a massive wave of new projects. Since 2017, $7.5 billion in investments have been announced across more than 70 projects capable of diverting 17.5 billion pounds [8.75 million tons]* from landfills."

Press release from American Chemistry Council, May 03, 2022

*** Over what time period? Total or per year?**

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Response to Oscar's question

Q: "If we could collect all the plastic in Michigan, what would we do with it?"

A. Mechanical recycling (shred jugs or bottles as fill)

B. Thermal recycling (sort, clean, heat, soften, pelletize, mold/stretch and harden/freeze into new jugs or bottles)

C. Chemical recycling (crack polymers into syngas, liquid fuels and char) – small- or large-scale

D. Monomer recycling (make monomers and fuels)

That's what we **CAN** do. But what **SHOULD** we do?

What's the best approach for recycling newly-collected plastic? Some guidelines

Minimize carbon footprint over the use/recovery material/product life-cycle

A. Always start with waste reduction

B. Maximize return of plastic waste to commerce

C. Minimize fossil fuel use and emissions

- **During processing**
- **For transportation**

D. Account for impacts of species sorts, removing contaminants, size reduction and densification

E. Dispose of the irreducible minimum

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Each approach has pros and cons

A. Mechanical recycling?

Low process energy, tolerant of contaminants and species

B. Thermal recycling?

Closed-loop recycling, requires good sort, low contamination

C Small-scale chemical recycling?

Minimize transport, offset fossil fuels, open-loop, phase in H2?

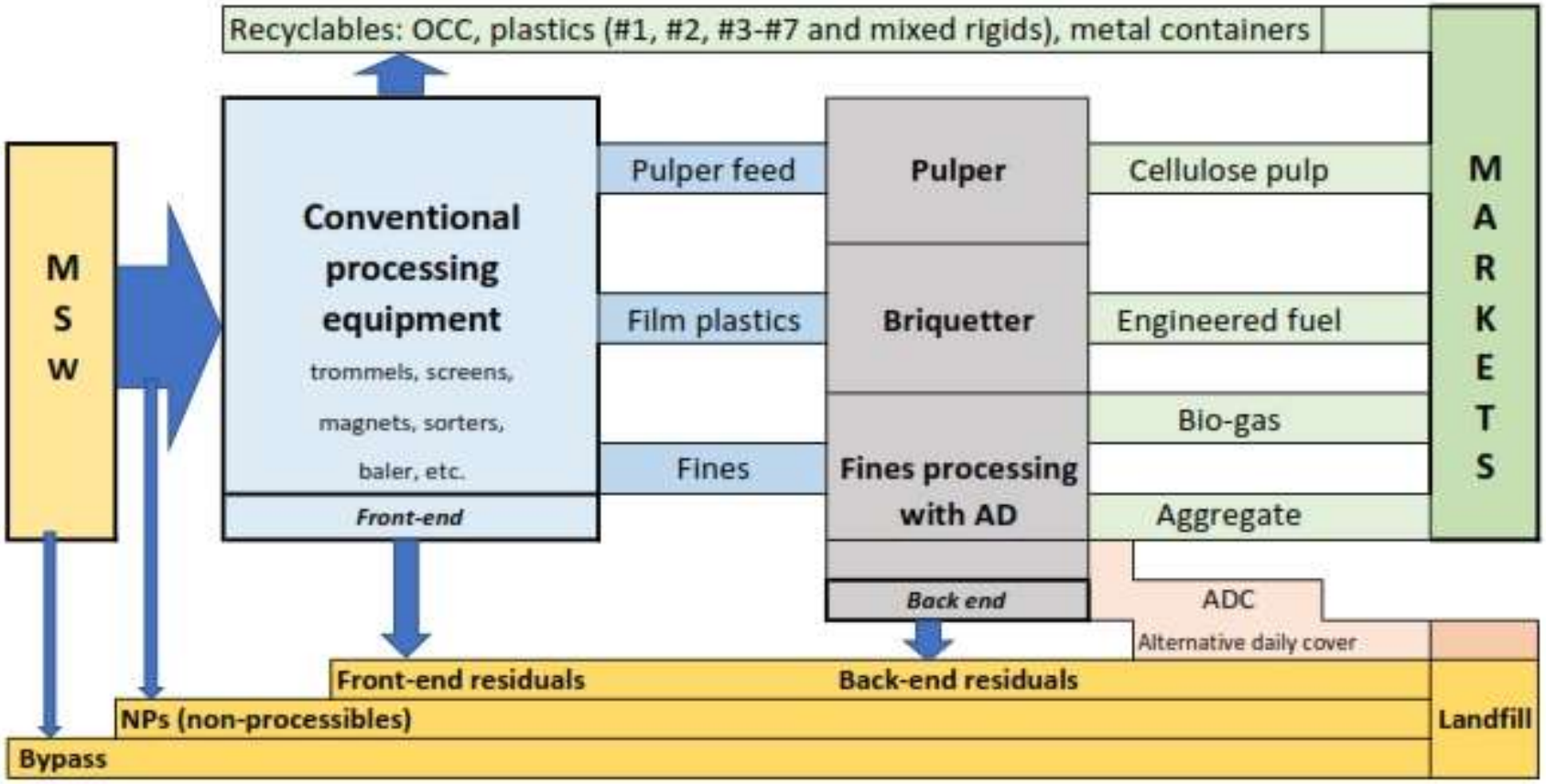
D. Large-scale chemical recycling?

Scale, provide essential fuels, open-loop, aggregation energy

E. Monomer recycling?

Scale, closed-loop materials, open-loop fuels, aggregation energy

What about mixed-MSW processing?



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What about mixed-MSW processing?

Kent Co. DPW proposal to Reimagine Trash
Selected vendors *Anaergia* and *Continuus Materials*
Convert 430,000 tpy MSW/SSRs to

- Bio-gas/RNG and fertilizer (organic fraction)
- Recyclable materials
- Roof coverboard material (Everboard) from low-value plastics and paper

Goal of 90% diversion by 2030

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What about mixed-waste processing?

Arguments for

- Recover materials from 100% of stream without relying on source separation
- Provide recycling services to unserved and remote areas without new local infrastructure
- Reduce transportation needs and impacts

Arguments against

- Recovered material quality and contaminants
- Less involvement of waste generators
- More sorting/processing requires more capex/opex

Plastic waste from mixed MSW processing

Coastal Resources Facility, Hampden Maine Photos by G Aronson

HDPE

Mixed rigids

Baled mixed plastic

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Plastic waste from mixed MSW processing

Coastal Resources Mixed MSW Processing Facility, Hampden, Maine

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Dragon Cement, Thomaston, Maine

SUMMARY

Plastics recycling in Michigan: change is coming!

New EGLE goal – 45% recycling

- collect more plastics; send less to landfills

New large-scale chemical recycling in northern Indiana

New large-scale monomer recycling across the US

Mixed-waste processing is on the horizon

Every approach has pros and cons

Will there be war for feedstock?

Let the competition begin!

Thank you for listening.

TOGETHER WE CAN
MICHIGAN RECYCLING COALITION 40TH ANNUAL CONFERENCE 2022

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