Sustainable Systems Research Foundation
Sustainable Procurement

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Today’s presentation:

• The approach
• The problem
• Why plastic recycling has failed
• Bottom-up, top-down, middle-out
• Our story thus far
Sustainable Procurement Integration Network (SPIN)

- A systems approach to propagating emerging best practice
- Build cooperative relationships with regional/local stakeholders to inform and transform default procurement choices
  - Agricultural producers
  - Regional food manufacturers
  - Local grocery chains
  - Institutions
  - Restaurants and take out
  - Local governments

- Middle-out: focus on the leveraging the interface between distribution and wholesale/institutional purchasers

- Simplify the back end by de-emphasizing recycling
Global plastics production, 1950 to 2015

Annual global polymer resin and fiber production (plastic production), measured in metric tonnes per year.

Source: Geyer et al. (2017)
IN 2016, PRODUCTION REACHED 396 MILLION METRIC TONS. THAT IS EQUIVALENT TO 53 KILOGRAMS OF PLASTIC FOR EACH PERSON ON THE PLANET.


INCREASE IN PLASTIC PRODUCTION BY 2030

396 MILLION METRIC TONS

Source: WWF 2019
“The **Sky** scenario illustrates a technically possible, but challenging pathway for society to achieve the goals of the Paris Agreement. **Sky** builds on previous Shell scenarios publications and is our most optimistic scenario in terms of climate outcomes.”
Today, most carbon in fossil energy production is burned and emitted to the atmosphere, while the CO₂ absorbed by wood and other plants used for energy is also returned to the atmosphere.

In **Sky**, at 2100, the bioenergy system has reached its resource base limit and is twice the size of the fossil energy system in CO₂ terms. The active management of CO₂ means that the total energy system is providing a drawdown of CO₂ from the atmosphere.

In **Sky**, in 2050, the storage of CO₂ is rapidly scaling up. There are equal contributions from the embedded carbon in materials production and CCS. Fossil energy CCS leads the way, but bioenergy CCS (BECCS) is close behind.

In **Sky**, in 2070, the energy system has achieved net-zero emissions. Fossil energy production is less than half today's level. Alongside direct CCS and the use of carbon for materials, the remaining fossil energy emissions are fully offset by captured CO₂ from an expanded bioenergy system.
Primary plastic production by industrial sector, 2015

Primary global plastic production by industrial sector allocation, measured in tonnes per year.

- Packaging: 146 million tonnes
- Building and Construction: 65 million tonnes
- Textiles: 59 million tonnes
- Other sectors: 47 million tonnes
- Consumer & Institutional Products: 42 million tonnes
- Transportation: 27 million tonnes
- Electrical/Electronic: 18 million tonnes
- Industrial Machinery: 3 million tonnes

Source: Geyer et al. (2017)
Mean product lifetime of plastic uses, 2015

Mean product lifetime (from production to disposal) of different uses of plastic products, measured in years.

- Building and Construction: 35 years
- Industrial Machinery: 20 years
- Transportation: 13 years
- Electrical/Electronic: 8 years
- Other sector: 5 years
- Textiles: 5 years
- Consumer & Institutional Products: 3 years
- Packaging: 0.5 years

Source: Geyer et al. (2017)
Balance of plastic production and fate (m = million tonnes)

8300m produced → 4900m discarded + 800m incinerated + 2600m still in use (100m of recycled plastic)

Total primary plastic production 8300m

Primary plastic still in use 2500m

Plastic used once 5800m

Incinerated 700m

Recycled 500m

Recycled then incinerated 100m

Recycled then discarded 300m

Straight to landfill or discarded 4600m

Source: based on Geyer et al. (2017). Production, use, and fate of all plastics ever made. This is a visualization from OurWorldinData.org, where you find data and research on how the world is changing. Licensed under CC-BY-SA by Hannah Ritchie and Max Roser (2018).
STOP! ALTO!
Removing cans and bottles is Theft!
Removiendo Botellas y Latas es Robando!
Call 911 to Report Theft
Plastic recycling doesn’t work

There are on the order of 20,000 plastics additives in common use today.¹

Industry-imposed plastic type identification codes are largely useless for recycling/upcycling. There is limited to zero industry standardization.

Recyclability is not just a function of plastic type, but of additive compatibility, recycling process, and previous life cycle history. Contamination, provenance, partial material degradation, and inconsistent properties are difficult and expensive to reliably control.

Single down-cycling to landfill/incineration is the default plastic “recycling” path.

Complicated, confusing, inconsistent, shifting “acceptable” individual behavior expectations is inefficient, ineffective, and evades manufacturer responsibility via cultural shaming.

“Compostable” plastics can cross-contaminate both recycling and compost streams.

High-resolution sorting, closed loop infrastructure, and materials standardization are necessary, but complicated, expensive and ultimately insufficient. They are essentially niche solutions.

¹ Goodsmith 2007
Fig. 2. The colour change in HDPE can be clearly seen after 10 process cycles. Virgin material (top left), material injection moulded and re-granulated 10 times (bottom left).
<table>
<thead>
<tr>
<th>Additive</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>Filler: generally used for cost reduction as much cheaper than polymer</td>
</tr>
<tr>
<td>Pigments</td>
<td>Give the plastic a colour. Generally for aesthetic properties</td>
</tr>
<tr>
<td>Glass fibre</td>
<td>Increased strength and stiffness</td>
</tr>
<tr>
<td>Flame retardants</td>
<td>Increase fire resistance</td>
</tr>
<tr>
<td>Heat stabilisers</td>
<td>Increased resistance to heat exposure</td>
</tr>
<tr>
<td>Light stabilisers</td>
<td>Increased resistance to light exposure</td>
</tr>
<tr>
<td>Plasticisers</td>
<td>Process aid which reduces viscosity</td>
</tr>
<tr>
<td>Foaming agents</td>
<td>Lightness and stiffness</td>
</tr>
</tbody>
</table>

Source: Goodship 2007
<table>
<thead>
<tr>
<th>Additive type</th>
<th>Example substance</th>
<th>Used in which plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticisers</td>
<td>Short, medium and long chain chlorinate paraffins. Phthalates: Bis (2-ethylhexyl)phthalate (DEHP), dibutylphthalate (DBP), di-2-ethylhexylphthalate (DPP). Adipates: diheptyl adipate (DHA), heptyl adipate (HAD), heptyl octyl adipate (HOA).</td>
<td>Mostly used in PVC and cellulose based polymers where they can make up to 75% w/w of the final product.</td>
</tr>
<tr>
<td>Flame retardants</td>
<td>Brominated flame retardants; polybrominated diphenylethers (PBDEs), decabromodiphenylethane. Phosphorous flame retardants; tris (2-chloroethyl)phosphate (TCEP), tris (2-chloroisopropyl)phosphate (TCPP).</td>
<td>Brominated compounds can reach 25% w/w of the final polymer.</td>
</tr>
<tr>
<td>Stabilisers, ultraviolet stabilisers, antioxidants</td>
<td>Bisphenol A (BPA) Cadmium and lead compounds Nonylphenols, octylphenols Butylated hydroxytoluene</td>
<td>Up to 3% w/w; phenolics generally added at lower amounts.</td>
</tr>
<tr>
<td>Slip agents</td>
<td>Fatty acid amides Fatty acid esters Zinc stearate</td>
<td>Added at up to 3% w/w depending on the polymer type.</td>
</tr>
<tr>
<td>Biocides</td>
<td>Organotins Arsenic compounds Triclosan</td>
<td>Added primarily to soft PVC and polyurethane foams.</td>
</tr>
<tr>
<td>Inorganic pigments</td>
<td>Cadmium, chromium and lead compounds Zinc oxide Iron oxide Titanium dioxide Lead carbonate Aluminium and copper powders</td>
<td>Non-fluorescing substances show lower migration rates.</td>
</tr>
<tr>
<td>Organic pigments</td>
<td>Cobalt(II) diacetate</td>
<td>Insoluble, low migration tendencies.</td>
</tr>
<tr>
<td>Fillers</td>
<td>Calcium carbonate Zinc oxide Barium sulphate Glass microspheres Nanomaterials Clays</td>
<td>Can make up to 50% w/w.</td>
</tr>
</tbody>
</table>

Source: Galloway 2019
Put in Mixed Recycling

- Aluminum Cans: No foil or trays
- Steel Cans: No scrap metal
- Cardboard & Pizza Boxes: No food or heavy grease
- Plastic Bottles, Plastic Tubs, Plastic To-Go Containers: Leave caps and lids on; No liquid or food waste
- Rigid Plastics: No electronics; Must fit in 96 gal cart; Minimal metal

DO NOT put in Mixed Recycling

- Glass must go in the Glass Recycling
- No plastic bags
- No Styrofoam
- No paper towels
- No shredded paper
- No aluminum trays
- No aluminum foil
- No hoses or other tanglers

KEEPS IT SIMPLE, KEEP IT CLEAN!

- Paper and Flattened Cardboard
- Glass Bottles and Jars
- Metal Cans & Aluminum
- Plastic Bottles Jugs, Jars & Tubes
- Plastic Bags Clean & Dry

NOT ACCEPTED IN THE BLUE CART

- No Single Plastic Bags
- No Food, Liquids, or Garbage
- No Cartons
- No Plastic Food Boxes
- No Polystyrene
- No Glassware or Ceramics
- No Pizza Boxes
- No Clothes or Linens
- No Tangles
- No Big Hams

When in Doubt - Find Out! 420-5593 cityofsantacruz.com/recycleright

EMPTY. CLEAN. DRY. It Matters.

RECYCLE RIGHT
Recyclable, compostable, or landfill?
“Sustainable” plastic is complicated

- Bio-based
- Degradable
- Biodegradable
- Compostable
- Composite

Each term implies very different characteristics. They are sometimes mutually exclusive. They are routinely used interchangeably to obfuscate the nature and implications of the materials they describe.

With a single exception (PHA variants), none are currently sustainable, compostable bioplastics. As with bioenergy, we’re still waiting for algae to save the day, real soon.

Some “sustainable” packaging solutions are as bad or worse than conventional plastics.
- Biobased or partially biobased non-biodegradable plastics such as biobased PE, PP, or PET (so-called drop-ins) and biobased technical performance polymers such as PTT or TPC-ET;
- Plastics that are both biobased and biodegradable, such as PLA and PHA or PBS;
- Plastics that are based on fossil resources and are biodegradable, such as PBAT.

Source: European Bioplastics 2019
Global production capacities of bioplastics

Source: European Bioplastics, nova-Institute (2019)
Global production capacities of bioplastics 2019 (by material type)

Total: 2.11 million tonnes

Bio-based/non-biodegradable: 44.5%
Biodegradable: 55.5%

*PEF is currently in development and predicted to be available in commercial scale in 2023.

Source: European Bioplastics, nova-Institute (2019)
• PLA is more degradable than biodegradable.

• Enzymes which hydrolyze PLA are not available in the environment except on very rare occasions.

Ecological studies on the abundance of PLA-degrading microorganisms in different environments have confirmed that PLA-degraders are not widely distributed, and thus it is less susceptible to microbial attack compared to other microbial and synthetic aliphatic polymers [10,11,34]. The degradation of PLA in soil is slow and that takes a long time for degradation to start [47,48].

Source: Tokiwa et. al. 2009
### Marine Degradation Reality

<table>
<thead>
<tr>
<th>Material</th>
<th>Initial % Carbon in 1 g sample</th>
<th>Cumulative Carbon Dioxide evolution after 180 days, g</th>
<th>% Biodegradation after 180 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mirel 4100 film</td>
<td>24.45</td>
<td>0.4041</td>
<td>45.08</td>
</tr>
<tr>
<td>Mirel 2200 film</td>
<td>24.12</td>
<td>0.3380</td>
<td>38.22</td>
</tr>
<tr>
<td>Cellulose powder</td>
<td>16.96</td>
<td>0.2071</td>
<td>33.31</td>
</tr>
<tr>
<td>PLA bag</td>
<td>17.09</td>
<td>0.0279</td>
<td>4.45</td>
</tr>
<tr>
<td>PLA bottle</td>
<td>17.43</td>
<td>0.0199</td>
<td>3.11</td>
</tr>
<tr>
<td>LDPE film</td>
<td>20.98</td>
<td>0.0254</td>
<td>3.3</td>
</tr>
</tbody>
</table>

*Source: CalRecycle 2012*
"We support applying the precautionary principle by banning oxo-degradable plastic packaging from the market until extensive, independent third-party research and testing based on international standards… possibly combined with technological progress and innovation, clearly confirms sufficient biodegradation of the plastic fragments in different environments, and over a time-scale short enough for particles not to accumulate in ecosystems."

"To create a system in which plastic packaging never becomes waste, we support innovation that designs out waste and pollution, and keeps products and materials in high-value use."
PLA doesn’t have a lower carbon footprint

Fig. 3 | GHG-emissions breakdown by life-cycle stage of plastics derived from different feedstock types under two energy-mix scenarios in 2050.

a. GHG emissions under the current energy-mix scenario in 2050. b. GHG emissions under a 100%-renewable-energy scenario in 2050. Emissions results are based on the scenario with a 4% yr⁻¹ growth rate for plastics demand and the projected EoL-management mix (Supplementary Table 10). Carbon credits generated by recycling are considered.

Source: Zhang 2019
Figure 1. PHA production chains

Source: EC 2014
Skipping plastic single use items entirely is a great alternative, but... widely marketed “compostable” paper/wood/fiber alternatives are sometimes worse.
Figure 3. Impact of plastic micromaterials and nanomaterials in organisms. Microplastics and/or nanoparticles can enter the circulation from the gut and lungs and accumulate in the gut, liver, and kidney resulting in several diseases. At the cell level, microplastics or nanoparticles can inhibit the efflux pump and mitochondria depolarization, induce reactive oxygen species (ROS). They also affect several signaling pathways, cause fibrosis, autophagy, and even DNA mutations. Many animal species have been contaminated by microplastics and/or nanoparticles. The figure was created with BioRender.com.
Our story thus far...

Comprehensive identification of best-practice products proceeds
Compostable certification standards propagate obfuscation
Lots of vaporware and corporate consolidation
Manufacturers often not forthcoming about material specifications
  • Mira
  • Biofase

Distribution chain is dominated by a few large companies.
Smaller distributors and direct contact with suppliers is promising
Working with food producers is promising
Group buys may be a place to start
Identifying good packaging design is promising

Mapping wholesale sourcing decisions is complicated sometimes
Working with institutions is surprisingly random
Working with retail stores/restaurants is promising
Many municipal governments are surprisingly obtuse
Please stay in touch

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