State-of-the-Art Sorting Technologies

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BETO Municipal Solid Waste (MSW) Workshop
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based on "A Crash Course in Plastic Recycling"
prepared by Dr. Brian Riise, REMADE
Clean Energy, Innovation & Sustainability

ACCELERATING THE TRANSITION TO A CIRCULAR ECONOMY

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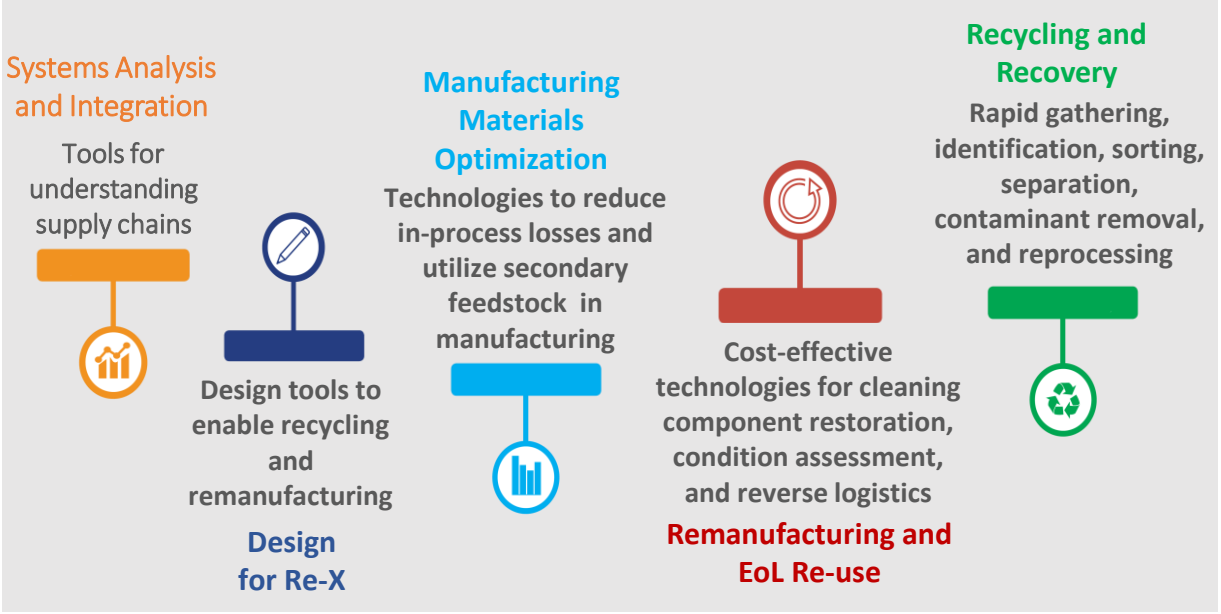
The REMADE Institute
Reduce EMbodied energy AnD carbon Emissions through early stage applied research & development

REMADE STRATEGIC GOALS

Enable **greater utilization of secondary feedstocks** which require less energy to produce for key materials

Reduce primary materials consumption (and energy lost when they are landfilled) while achieving better than cost and energy parity for key secondary materials

Promote **widespread application of new technologies** across multiple industries that expand material recycling, recovery, remanufacturing and reuse in US manufacturing



REMADE is a public/private partnership developing transformational technologies to accelerate the transition to a Circular Economy for plastics, metals, fibers and e-waste

 Funding provided by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under Advanced Manufacturing Office Award Number DE-EE0007897.

Technology Innovation: Current R&D Portfolio

30 Projects

45 Collaborating Organizations

$15 Million Project Value

13 Projects
$7.7M Project Value

Recycling and Recovery

7 Projects
$2.3M Project Value

Remanufacturing/ EOL Reuse

5 Projects
$2.6M Project Value

Systems Analysis and Integration

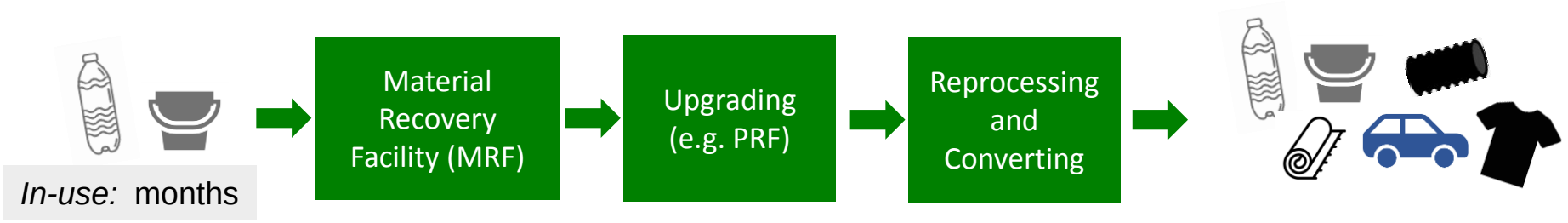
3 Projects
$0.6M Project Value

Design for Re-X*

3 Projects
$1.7M Project Value

Manufacturing Materials Optimization

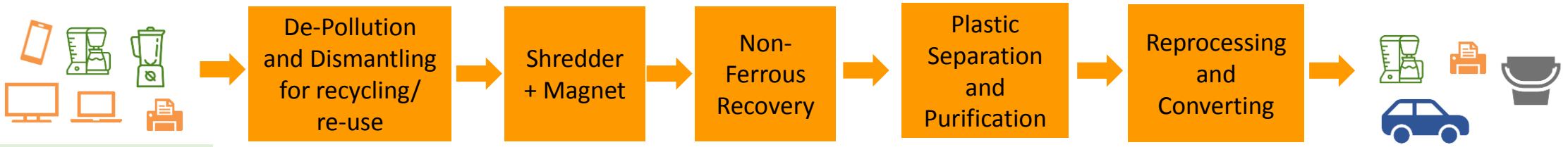
Example End-of-Life Plastics Streams[1-9]



In-use: months

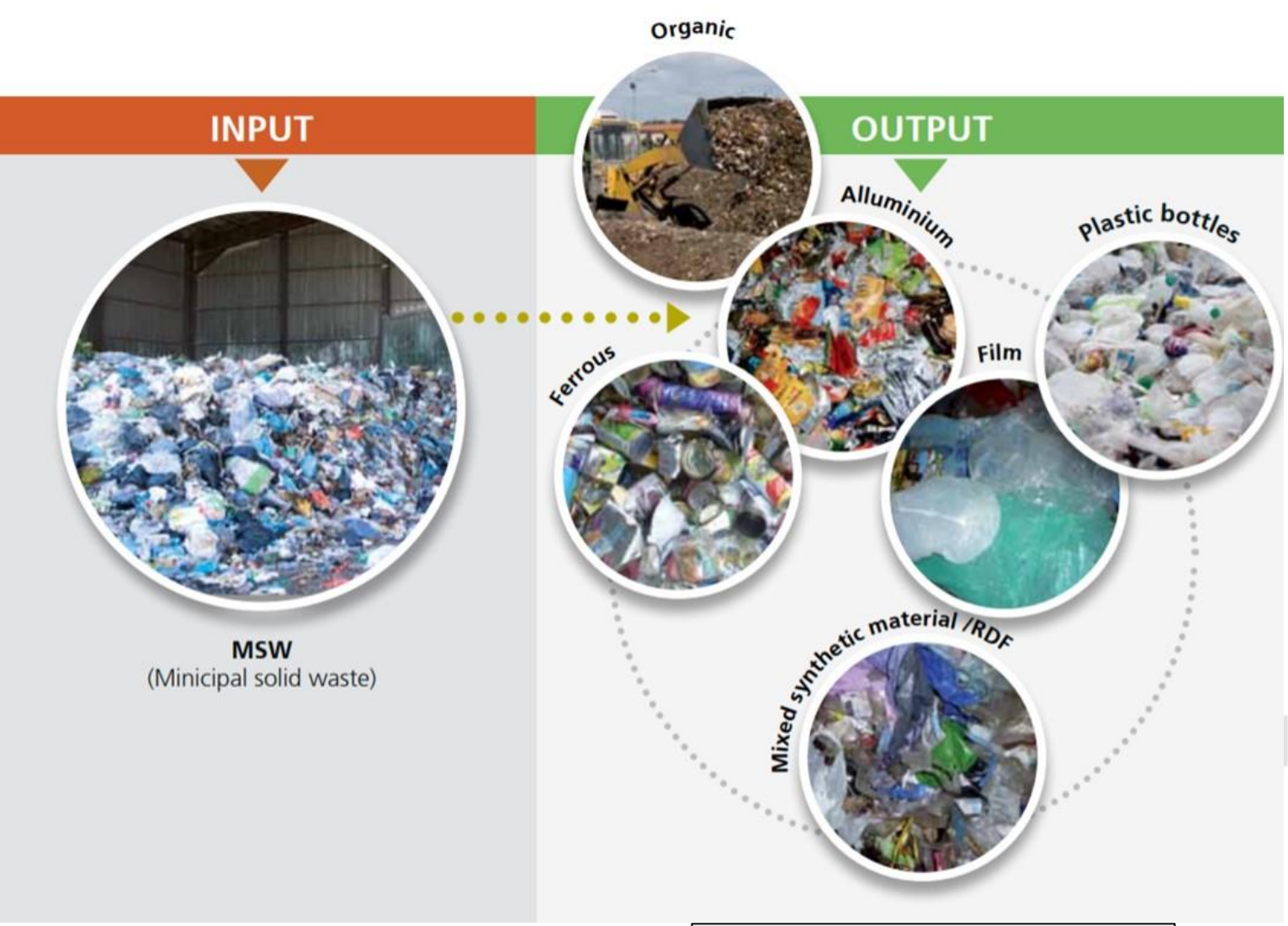
In-use: a few hours

In-use: 10-20 yrs



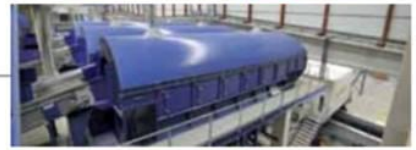
In-use: 5-15 yrs

Material Recovery Facilities



- Bag opener
- Shredder

- Manual pre-sorting
- Screening drum



- Ballistic separator
- Air classifier

- Magnetic separator
- Eddy current separator

- Near-infrared separator

- Bunker conveyors

- Baling press
- Shredder (RDF)

Photos and Graphics courtesy of STADLER America LLC

Processes to Recover Plastics from Mixed Streams

Size Reduction

Photo courtesy of SSI Shredding Systems, Inc.

Plastic Cleaning

Photo courtesy of Herbold Meckesheim GmbH

Drawing courtesy of Hamos GmbH

Removal of non-plastics

Plastic-Plastic Separation

Photo courtesy of MSS Inc.

Compounding, de-gassing and melt filtration

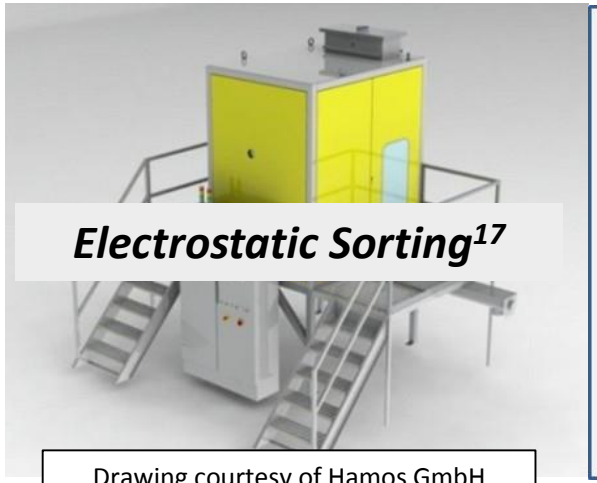
Photo courtesy of Starlinger

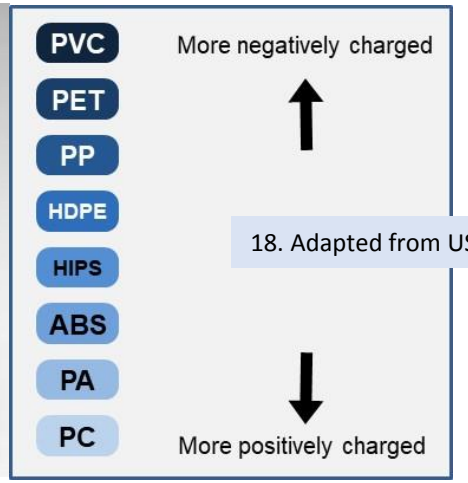
Plastic-Plastic Separations

- Several separation steps required
- Particle size is important[12]
- Sequence is important

Plastic	Specific Gravity[13]
PP	0.92
HDPE	0.94
PS	1.05
PET	1.38
PVC	1.38

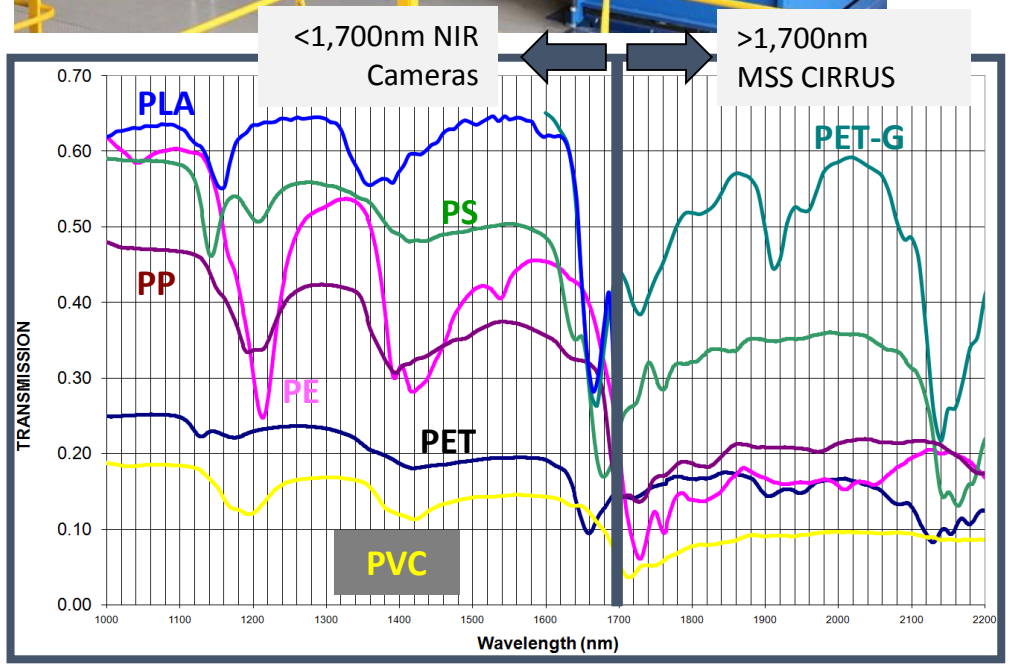
- Color
- NIR
- X-Rays (T, F)
- metal detector
- other
- combination

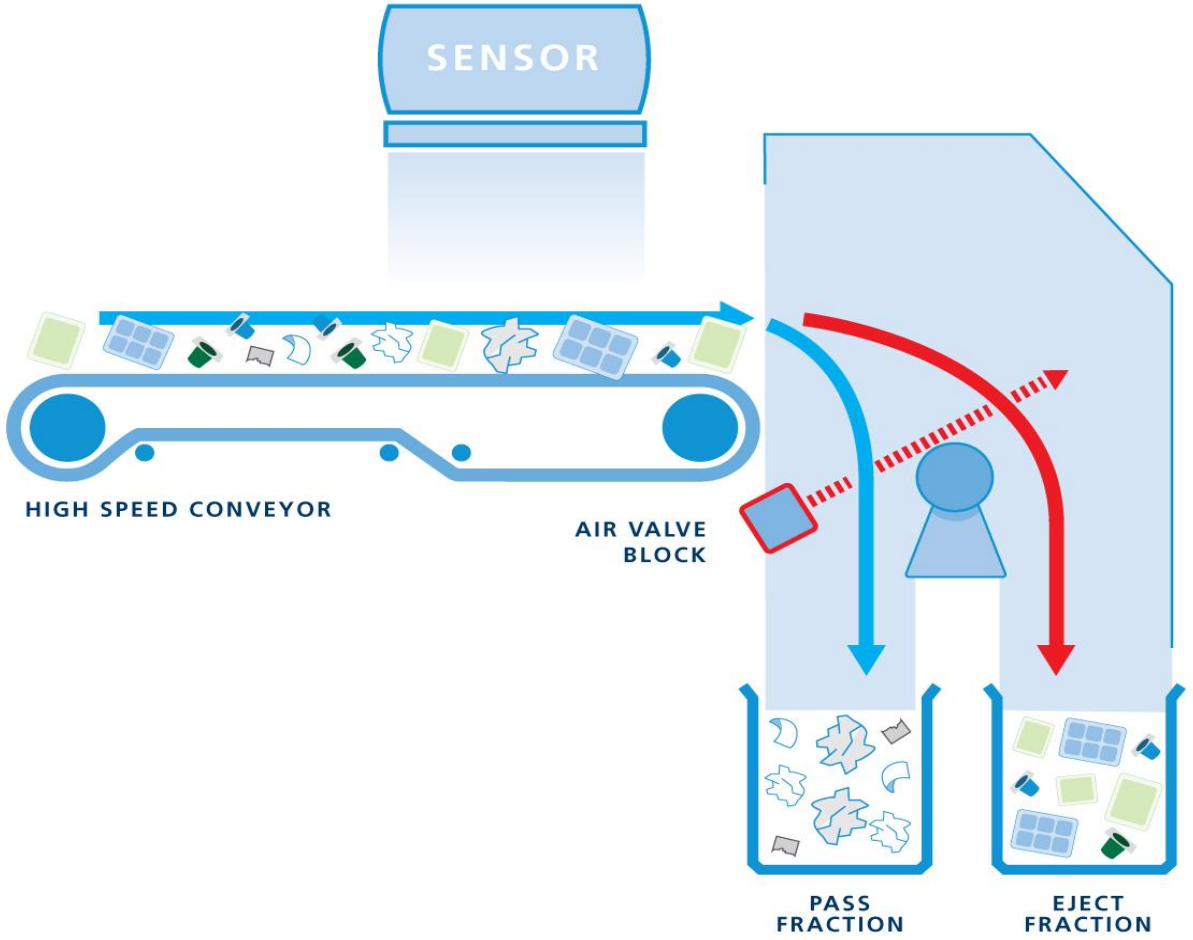




18. Adapted from US 6,452,126

Example: NIR Sorting of Plastics

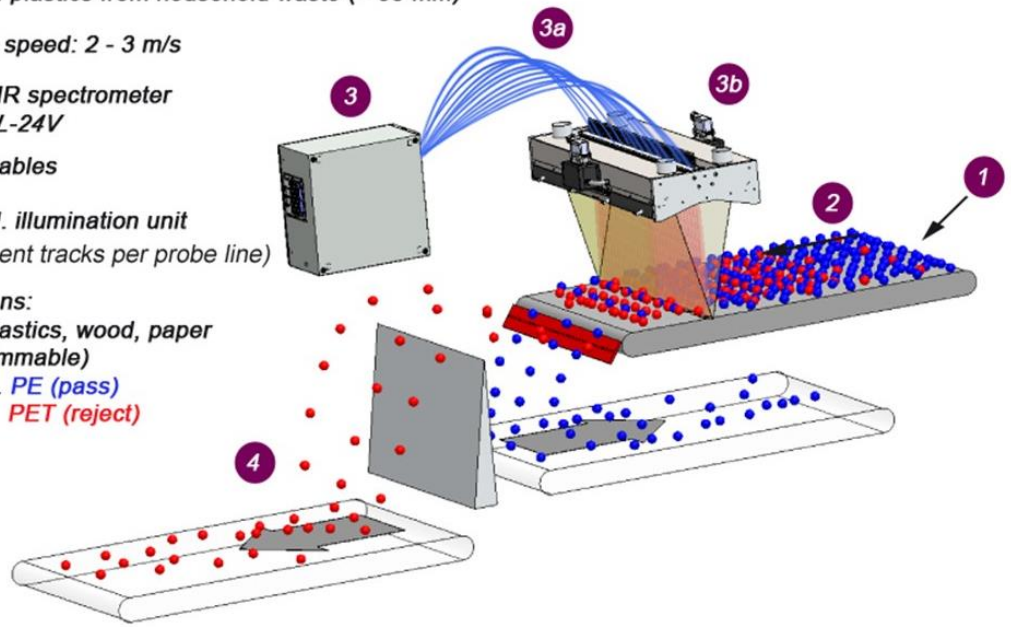


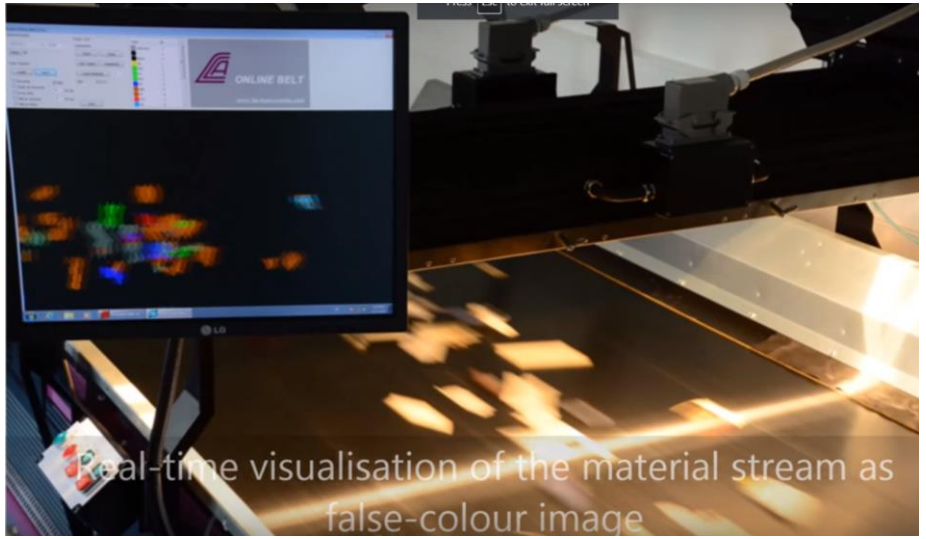


- Commonly used for PET, HDPE and PP containers
- ***Cannot "see" black plastics!*** [20-26]

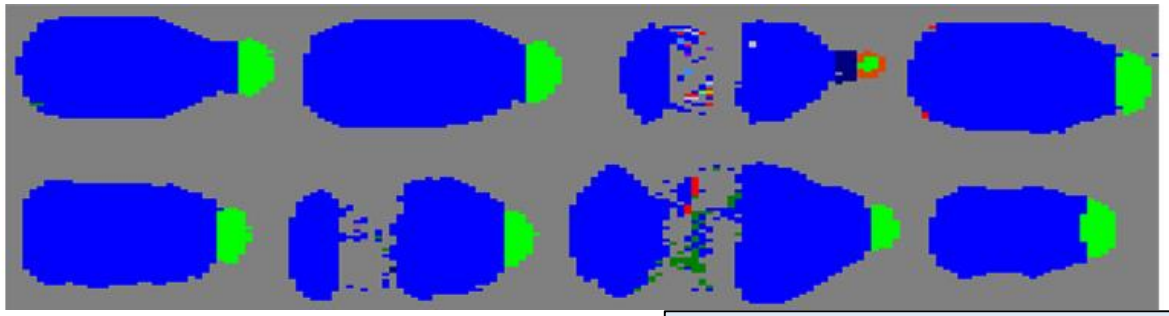
Plastic Identification with NIR

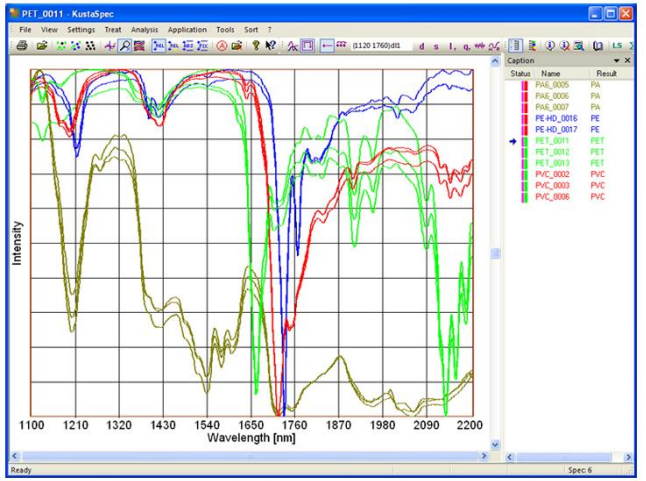
1. Input material: plastics from household waste (> 30 mm)
2. Conveyor belt speed: 2 - 3 m/s
3. Multiplexed NIR spectrometer KUSTAx.xMPL-24V
3a. Optical fiber cables
3b. Probe line incl. illumination unit (64 measurement tracks per probe line)
4. Sorting fractions: all common plastics, wood, paper (freely programmable) Fractions: e.g. PE (pass) PET (reject)





Type	ID
unknown	-3
---	0
Black	0
PET	2
PE	3
PP	4
PS	5
PVC	6
PA	7
PC	8
ABS	9





Images courtesy of LLA Instruments, Berlin

Also show videos such as https://www.youtube.com/watch?time_continue=152&v=eIZIWSj7jIg, https://www.youtube.com/watch?v=W5I00JcCdZE&feature=youtu.be (longer video with flakes) or https://www.youtube.com/watch?v=sB2wcaWqeT8&feature=youtu.be (short video household plastics) or https://www.youtube.com/watch?v=W5I00JcCdZE&feature=youtu.be (E-Waste)

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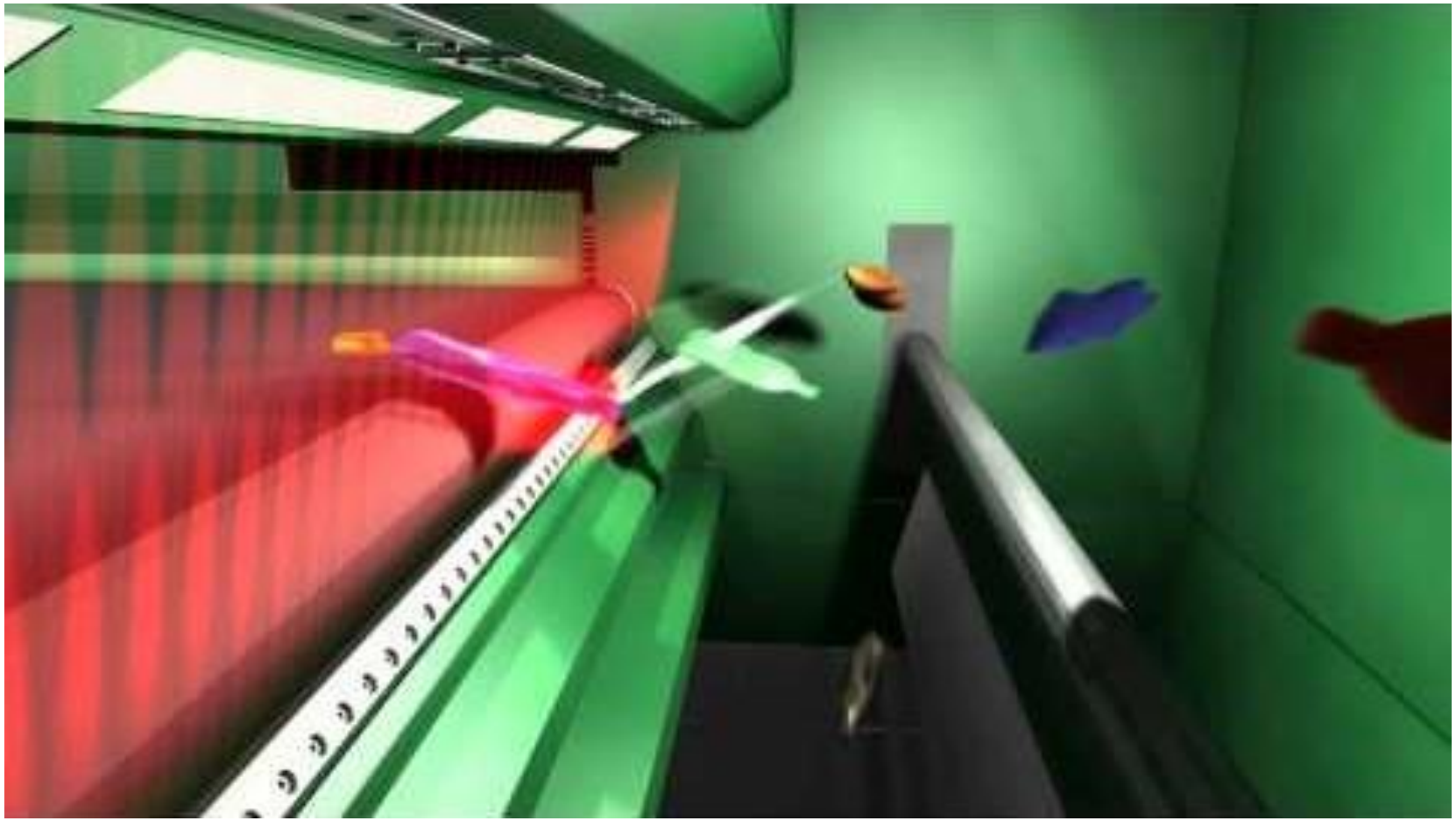
Plastic Sorting



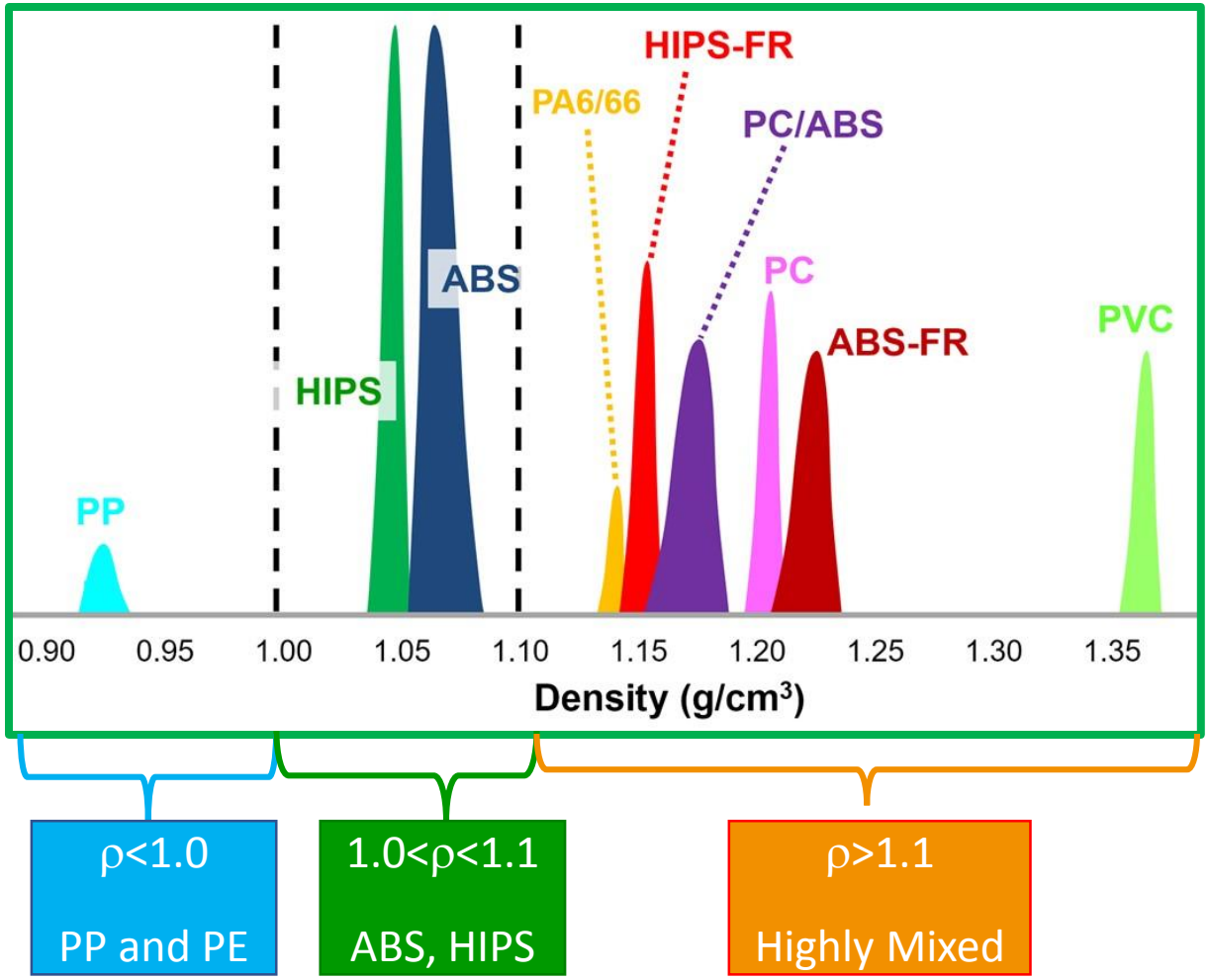
Video courtesy of Bulk Handling Systems (BHS)

Artificial Intelligence & Robotics

Video courtesy of AMP Robotics)

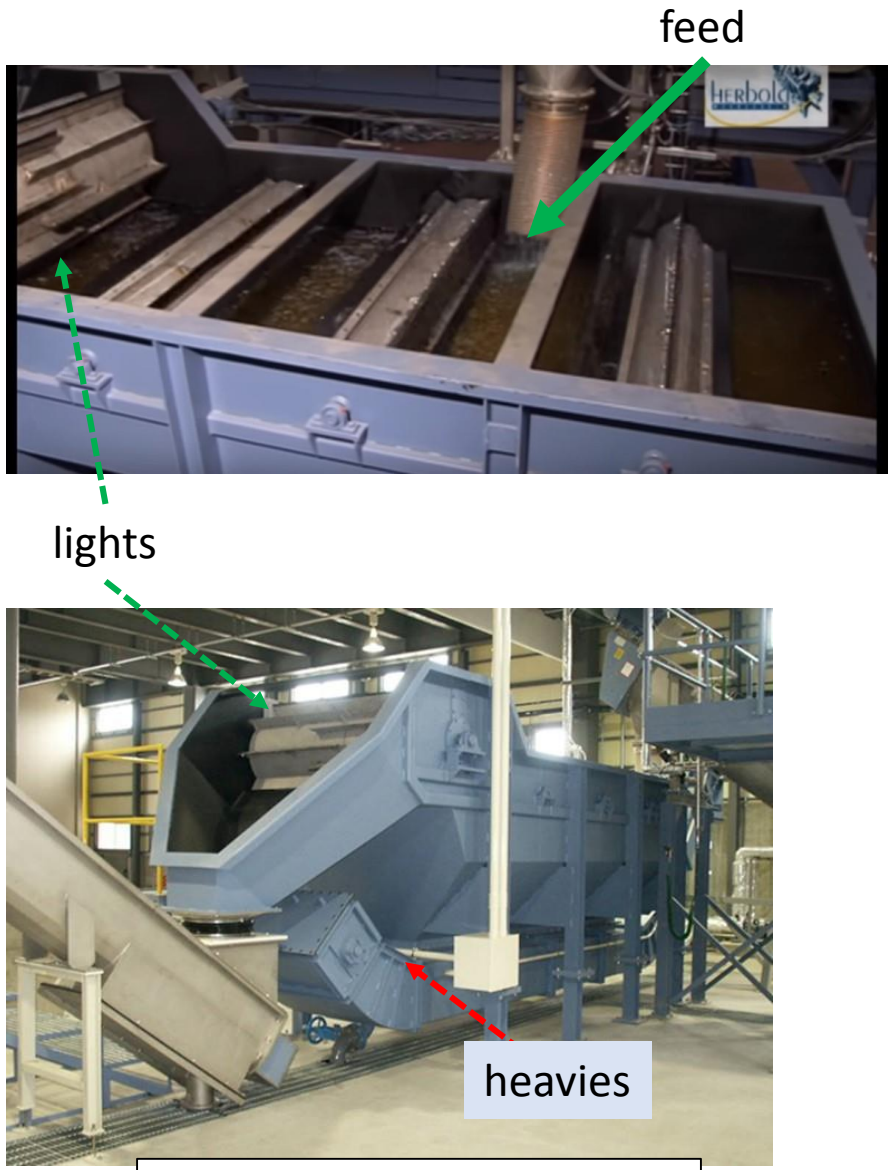
Why Separate by Density?

Plastic type	Specific gravity[13]
PP	0.92
HDPE	0.94-0.95
(HI)PS	1.03-1.05
ABS	1.05-1.08
PA	1.14
PET	1.38
PVC	1.38



Density Separation Methods[14-15,27]

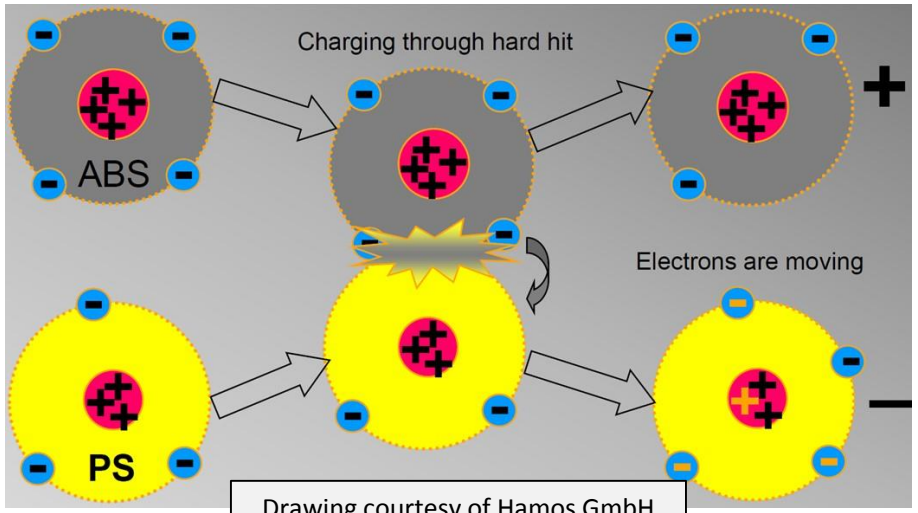
- Sink-float
- Drum separator
- Hydrocyclones
- Elevated density
  - Salt solutions
  - Suspended solids (magnetite, calcium carbonate)
  - Water-only (jigging, tabling, spiral, upward flow/terminal velocity)
- Reduced density
  - Water/alcohol mixtures
  - Suspended solids (hollow glass spheres)
  - Magnetic density separations (see TU Delft process[28])
  - Baffled Oscillation Separation System (BOSS) to separate PP from PE)[29]
- Froth flotation[30]



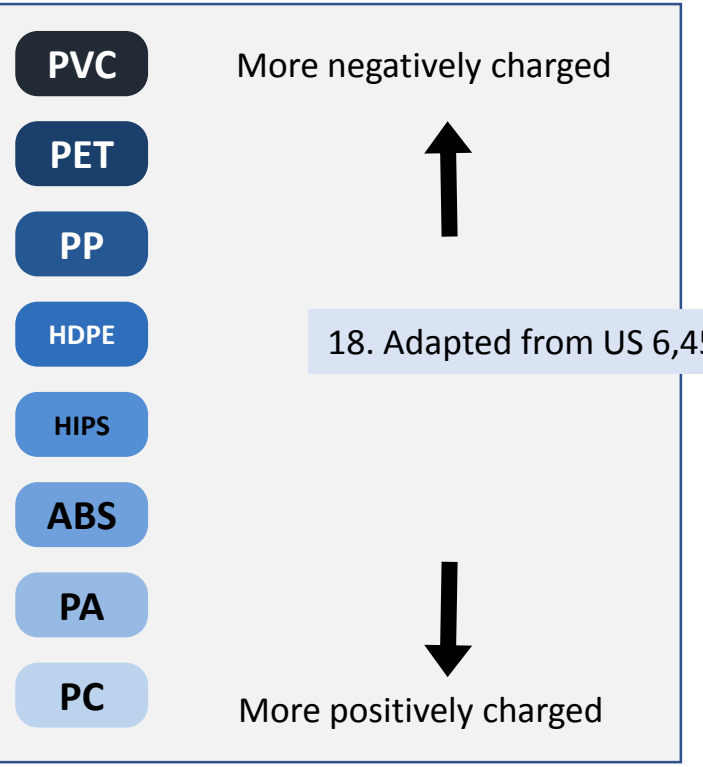
Photos courtesy of Herbold Meckesheim GmbH

Electrostatic Sorting of Plastics[17,31]

- Most commonly used on mixtures of plastics of similar density (e.g. ABS and HIPS)
- Can sort black plastics (unlike NIR)
- Based on differential charging of different plastics
- Plastic flakes are dry and (often) hot
- Performed on smaller particles (e.g. <10 mm)



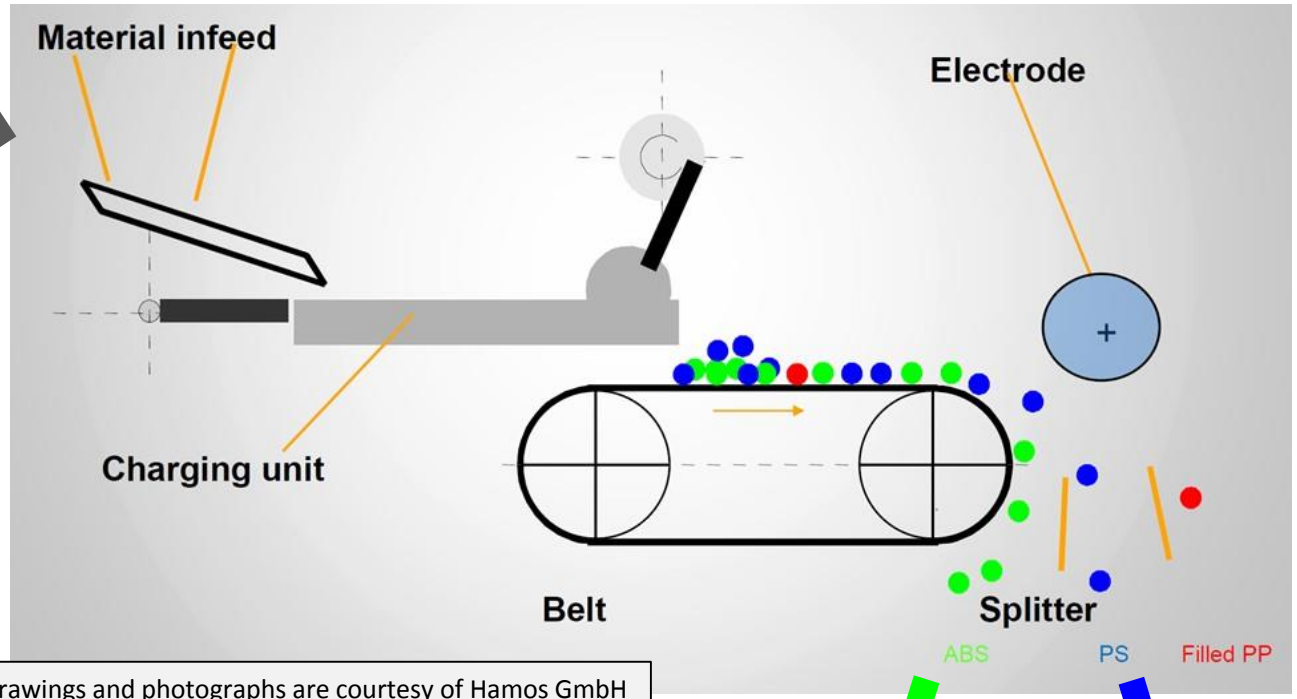
Drawing courtesy of Hamos GmbH

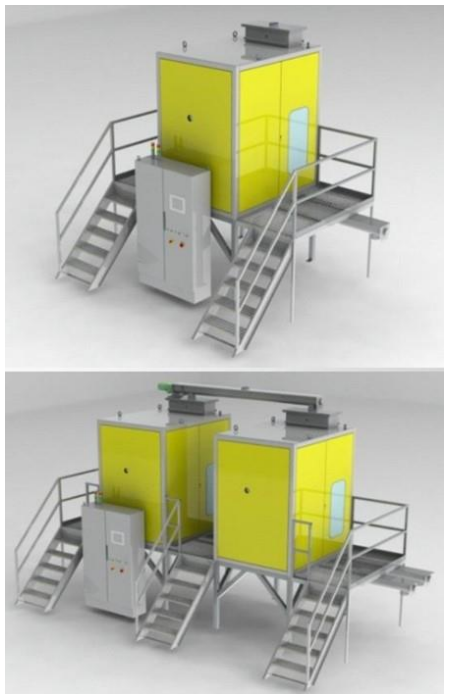


18. Adapted from US 6,452,126

Electrostatic Sorting of Plastics[17,31]

WEEE (E-Waste)
ABS/HIPS mix





Drawings and photographs are courtesy of Hamos GmbH

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Review of Separation Processes to Recover Plastic Flakes

- Multiple Process steps are required
  - Size Reduction
  - Cleaning
  - Removal of non-Plastics
  - Plastic-Plastic Separation
- Two are more steps for each process type may be required
- Sequence and number of steps depends on the material stream and targeted products
- Do we have a product suitable for use by converters (injection molding, extrusion into sheet pipe or profiles, etc.)?

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The REMADE Institute

https://remadeinstitute.org/

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Acknowledgements (1 of 3)

- Permissions from the following companies were given for use of their images, and several also provided feedback to the content created for the Plastics Recycling training modules (continued on next slide)
  - Dow Chemical (https://www.dow.com/en-us.html)
  - Association of Plastics Recyclers (APR) (https://plasticsrecycling.org/)
  - Milliken (https://chemical.milliken.com/products/additives-nucleating-agents-polyethylene-polypropylene-hyperform-hpn)
  - Titus MRF Serices (https://titusmrfservices.net/)
  - SSI Shredding Systems (https://www.ssiworld.com/en)
  - Herbold Meckesheim GmbH (www.herbold.com/en/)
  - Eriez (https://www.eriez.com/NA/EN/eriez.htm)
  - Kice (https://www.kice.com/)
  - Forsberg's Inc. (http://forsbergs.com/)
  - Triple S Dynamics (https://www.sssdynamics.com/)
  - STADLER America LLC (http://www.w-stadler.com/)
  - Bulk Handling Systems (BHS) (https://www.bulkhandlingsystems.com/)
  - MSS (www.mssoptical.com/material-sorting-equipment/)
  - Hamos (http://www.hamos.com/,,eng)
  - EREMA (www.erema.com/us/home/)
  - Unisensor Sensorsysteme GmbH (https://www.unisensor.de/en.html)
  - Tomra (https://www.tomra.com/en/sorting/recycling/tomra-solutions)

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Acknowledgements (2 of 3)

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  - LLA Instruments (https://www.lla-instruments.com/)
  - Starlinger (https://www.starlinger.com/en/recycling/)
  - Gneuss (https://www.gneuss.com/en/)
  - Parkinson Technologies (https://www.parkinsontechnologies.com/products/key-filters)
  - Ettlinger (a Maag company) (https://www.ettlinger.com/en/)
  - Fimic (https://www.fimic.it/en)
  - Maag (https://maag.com/applications/extrusion/)
  - Gala (a Maag Company) (http://www.gala-industries.com/)
  - Coperion (https://www.coperion.com/en/products-services/extruders-compounding-machines/)
  - Instron (http://www.instron.us/en-us)
  - Testing Machines Inc. (www.testingmachines.com)
  - TA Instruments (http://www.tainstruments.com)
  - BOY Machines Inc. (http://www.boymachines.com/)
  - Perkin Elmer (http://www.perkinelmer.com/)
  - Bruker Optics (https://www.bruker.com/)
  - Thermo Fisher Scientific (https://www.thermofisher.com/us/en/home/industrial/spectroscopy-elemental-isotope-analysis.html)
  - AMP Robotics (https://www.amprobotics.com/)

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Acknowledgements (3 of 3)

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  - The education committee of the PLASTICS Industry Association (https://www.plasticsindustry.org/)
  - REMADE members providing feedback about training requirements
  - Other polymer producers and additive suppliers not listed previously
  - Former colleagues (Mike Biddle, Trip Allen, Ron Rau, Scott Farling, and many others)
  - Scott Mouw of The Recycling Partnership

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