LITERATURE REVIEW: USING RECYCLED PLASTICS FOR COMPOUNDING AND ADDITIVES

New End Market Opportunities (NEMO) for Film

May 29, 2018
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INTRODUCTION

Recycled plastics are a valuable resource and feedstock for manufacturing. Some plastics, like bottles, will be recycled back into similar applications, but often, recycled plastics are used for entirely different products than their initial application. Just like virgin plastics, recycled materials have many desirable attributes, which can be used to improve properties of other plastics and non-plastic materials. The plastics industry is committed to furthering new uses for recycled plastics, which requires innovative thinking about how, and where we use recycled materials.

This document consolidates prior research and news coverage of new and non-traditional uses for recycled plastics. The Plastics Industry Association (PLASTICS) hopes the information contained in this literature review will inspire innovation and new opportunities for all streams of recycled plastics.

Special thanks to the PLASTICS New End Market Opportunities (NEMO) for film workgroup for commissioning this document and making it freely available.
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<th>Article Title</th>
<th>Product application</th>
<th>Recycled plastics used</th>
<th>Percentage of recycled materials used</th>
<th>Benefits</th>
<th>Challenges</th>
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<tr>
<td><strong>System for making synthetic wood products from recycled materials</strong></td>
<td>Building blocks</td>
<td>LDPE, HDPE</td>
<td>15% plastic material</td>
<td>Uses waste wood fiber and recycled plastics instead of virgin wood</td>
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<td><strong>Economic and Environmental Comparison of Post-Consumer Recycled Polyethylene and Virgin Polyethylene Trash Bags</strong></td>
<td>Trash bags</td>
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<td><strong>Development of new lubricating grease formulations using recycled LDPE as rheology modifier additive</strong></td>
<td>Lubricating greases</td>
<td>LDPE</td>
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<tr>
<td><strong>Potential of using recycled low-density polyethylene in wood composites board</strong></td>
<td>Wood boards</td>
<td>LDPE</td>
<td>50%</td>
<td>Reduce wood consumption and increase strength of wood boards</td>
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<tr>
<td><strong>Valorisation of waste plastic bags in cement-mortar composites as coating of local sand aggregates: physicomechanical characterization and potential uses</strong></td>
<td>Cement</td>
<td>LDPE</td>
<td>8-12%</td>
<td>Reduces waste of plastic bags, reduced water absorption ratio by 90% and decreased density by 11.6%</td>
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<td><strong>LDPE/EPDM Multilayer Films Containing Recycled LDPE for Greenhouse Applications</strong></td>
<td>Greenhouse films</td>
<td>LDPE</td>
<td>25 - 50%</td>
<td>Using recycled LDPE reduces cost</td>
<td>Addition of EPDM necessary to reduce effect of weathering on LDPE only film. EPDM film retained 75-95% original extensibility after 9 months of weathering</td>
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<td>Experimental tests and technical characteristics of regenerated films from agricultural plastics</td>
<td>Agricultural plastic films</td>
<td>LDPE, HDPE</td>
<td></td>
<td>Doesn't require any additives in the blends</td>
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<td>Polyethylene and biodegradable mulches for agricultural applications: a review</td>
<td>Biodegradable mulch, agricultural mulch film</td>
<td>PE</td>
<td></td>
<td>more efficient use of soil nutrients, reduction of insect pests, moisture conservation, higher crop yield</td>
<td>breakdown of mulch sometimes unpredictable, more research needed</td>
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<tr>
<td>Novel recycled polyethylene/ground tire rubber/bitumen blends for use in roofing applications: Thermo-mechanical properties</td>
<td>Roofing and waterproofing applications</td>
<td>PE</td>
<td></td>
<td>Use of recycled PE increases material elastic and viscous properties at high temperatures</td>
<td>GTR (ground tire rubber) required to improve material behavior at low temperatures</td>
</tr>
<tr>
<td>Tightening the loop on the circular economy: Coupled distributed recycling and manufacturing with recyclebot and RepRap 3-D printing</td>
<td>3-D Printing filament</td>
<td>PE (ABS?)</td>
<td></td>
<td>Use of recycled materials reduces embodied energy by half and reduces cost of final consumer product</td>
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<tr>
<td>Method for producing a supply obtained from the recycling of plastic material of industrial and post-consumer residues, to be used by 3-D printers</td>
<td>3-D Printing filament</td>
<td>PET, PA</td>
<td>Up to 100%</td>
<td>Recycled 3-D printer filament can be used for commercial and home use</td>
<td>Source is patent claim - not in production yet</td>
</tr>
<tr>
<td>Recycling in buildings: an LCA case study of a thermal insulation panel made of polyester fiber, recycled from post-consumer PET bottles</td>
<td>Thermal insulation</td>
<td>PET</td>
<td>100%</td>
<td>Saves more energy than thermal insulation panels made with virgin PET</td>
<td></td>
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<tr>
<td>The effect of post-consumer PET particles on the performance of flexible polyurethane foams</td>
<td>Flexible foams</td>
<td>PET</td>
<td></td>
<td>Tensile resistance, strain at break, and tear resistance improved with use of post-consumer PET, as did compression set, compression resistance, and wear</td>
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<tr>
<td>Valorization of post-consumer waste plastic in cementitious concrete composites</td>
<td>Concrete composite</td>
<td>PET</td>
<td>&lt;50%</td>
<td>Addition of post-consumer PET doesn’t affect compressive strength or flexural strength of concrete composites and would save energy</td>
<td></td>
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<tr>
<td>Composite material from fly ash and post-consumer PET</td>
<td>Concrete composite</td>
<td>PET</td>
<td>&gt;50%</td>
<td>Fly ash was found to improve the use of post-consumer PET in composites - reduces thermal decomposition of PET, expedites melting &amp; mixing of PET, reduces shrinkage of PET during molding process, increases compressive strength</td>
<td></td>
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<tr>
<td>Potential applications of 3-D printing in the recycling of fishing nets &amp; ropes</td>
<td>3-D Printing filament</td>
<td>RPFs: PLA, ABS, HIPS, PVA, PET, PA, PC</td>
<td>100%</td>
<td>Conclusion was that more research was needed, but has potential to reduce waste in small fishing communities</td>
<td>Limited success - contaminants compromised materials and caused damage to printer nozzles. More research needed</td>
</tr>
<tr>
<td>Thermal insulation enhancement in concretes by adding waste PET and rubber pieces</td>
<td>Concrete composite</td>
<td>PET</td>
<td></td>
<td>Addition of PET bottle pieces improves thermal insulation and reduces heat loss</td>
<td></td>
</tr>
<tr>
<td>Recycling of PET bottles as fine aggregate in concrete</td>
<td>Concrete composite</td>
<td>PET</td>
<td>5%</td>
<td>used un-washed PET bottles (WPET) and was found to have similar workability characteristics, compressive strength, a moderately higher ductility and only a slightly lower tensile strength</td>
<td></td>
</tr>
<tr>
<td>Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles</td>
<td>Concrete composite</td>
<td>PET, WPLA</td>
<td>25%</td>
<td>Did multiple tests on amount of WPLA (25, 50, 75%), 25% was found to have the best structural efficiency</td>
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<td>Recycled milk pouch and virgin LDPE-LLDPE-based jute fiber composites</td>
<td>Jute fiber composites</td>
<td>LLDPE, LDPE</td>
<td>100%</td>
<td>50/50 blend of virgin and recycled LDPE/LLDPE performed much better than 100% recycled jute fiber composite</td>
<td>100% recycled jute fiber has worse mechanical properties and poorer thermal stability compared to virgin polymer/jute fiber composites</td>
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<td>Blending LLDPE and Ground Rubber Tires</td>
<td>Polymer blend</td>
<td>LLDPE</td>
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<td>Mechanical Properties and Crystallization Behavior of PP/Wood Flour Composites</td>
<td>Polymer blend</td>
<td>PP</td>
<td></td>
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<td>Increased tensile strength when PP added</td>
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<td>Study on Modified PE for Wood Fiber-Plastic Composite Manufacture</td>
<td>Wood composite</td>
<td>LLDPE</td>
<td></td>
<td></td>
<td>LLDPE with maleic anhydride was studied for use in a wood fiber-plastic composite</td>
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<tr>
<td>Structure and properties of compatibilized recycled poly(ethylene terephthalate)/linear low density polyethylene blends</td>
<td>Polymer blend</td>
<td>LLDPE, PET</td>
<td></td>
<td>Tensile properties improved, elongation at break and charpy impact strengths increased with addition of SEBS/SEBS-g-MA</td>
<td></td>
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<tr>
<td>Study of recycled polyethylene materials as asphalt modifiers</td>
<td>Asphalt</td>
<td>LDPE</td>
<td></td>
<td>LDPE w/ lower molecular weight and wider molecular weight distribution was found suitable for asphalt modification</td>
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<tr>
<td>The theoretic analysis and experimental study on PE modified asphalt</td>
<td>Asphalt</td>
<td>LDPE</td>
<td></td>
<td>Found that LDPE modified asphalt increases high-temperature stability and may improve aging performance</td>
<td></td>
</tr>
<tr>
<td>Utilization of waste plastic in asphalting of roads</td>
<td>Asphalt</td>
<td>LDPE</td>
<td>30%</td>
<td>Found that LDPE modified asphalt has better binding property, stability, density, and is more resistant to water</td>
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<td>Research of mixed-waste plastics from urban waste as road bitumen modifier</td>
<td>Asphalt</td>
<td>LDPE, HDPE, PP</td>
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<td>Wood flour-reinforced plastic composites: A review</td>
<td>Polymer blend</td>
<td>HDPE, LDPE, LLDPE, PP</td>
<td></td>
<td>Wood flour reinforced plastic has improved mechanical, chemical, and thermal properties</td>
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<td>Evaluation of corn husk fibers reinforced recycled low-density polyethylene composites</td>
<td>Polymer blend</td>
<td>LDPE</td>
<td></td>
<td>Studied characteristics of LDPE and corn husk fiber blend for packing applications, found positive results</td>
<td></td>
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<tr>
<td>3DPro-Development of low cost prosthetics using 3D printing technologies</td>
<td>3D Printed Prosthetics</td>
<td>PE</td>
<td></td>
<td>Unsure of how relevant this paper was but it's the only thing i've found of its kind - looks at 3D printing of prosthetics in 3rd world countries with recycled plastic</td>
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<tr>
<td>LLDPE/PP Blends in tubular film extrusion: Recycling of mixed films</td>
<td>Polymer blend</td>
<td>LLDPE 85%</td>
<td></td>
<td>Studied mechanical properties of 85/15 LLDPE/PP mixture, found positive results for tear and impact strength</td>
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<tr>
<td>Recycled plastic used in concrete paver block</td>
<td>Concrete Paver</td>
<td>PET, PP 10%, 20%, 30%</td>
<td></td>
<td>Would reduce overall waste if concrete aggregates could be replaced with recycled plastic</td>
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<tr>
<td>Strength and behavior of concrete contains waste plastic</td>
<td>Concrete composite</td>
<td>PE 1%, 3%, 5%</td>
<td></td>
<td>Compressive, tensile, and flexural strength of concrete declined as amount of plastic increased in the mixture</td>
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<tr>
<td>Recycling of polyethylene films used in greenhouses - Development of multilayer plastic films</td>
<td>Multilayer plastic films</td>
<td>PE, LLDPE</td>
<td></td>
<td>Experiment found success in using multilayered film (with bottom layer composed of PE waste) as greenhouse films</td>
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<td>Production of recycled plastic aggregates and its utilization in concrete</td>
<td>Concrete composite</td>
<td>recycled plastic aggregate</td>
<td></td>
<td>Aggregate was lightweight, comparable density and strengths to other aggregates</td>
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<td>Blown film extrusion of post-consumer recycled LLDPE film</td>
<td>Plastic film</td>
<td>LLDPE</td>
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<td>Blown film made of mix of post-consumer and virgin LLDPE. Tested for dart drop impact strength, cross and machine direction tear strength, and gauge uniformity</td>
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<td>Characteristics of starch-filled LLDPE plastic processed from plastic waste</td>
<td>Plastic composite</td>
<td>LLDPE</td>
<td></td>
<td>Study contrasted virgin LLDPE with rice starch added and recycled LLDPE with rice starch. Virgin LLDPE with rice starch added increased melt flow index of LLDPE but MFI decreased with recycled LLDPE.</td>
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<tr>
<td>Recycle of waste LDPE/PA6/LLDPE Composite film</td>
<td>Composite film</td>
<td>LDPE, LLDPE</td>
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<td>Tested waste air bag with LDPE/PA6/LLDPE base material with LDPE-g-MAH as compatibilizer. Mechanical properties improved in blend as well as barrier properties</td>
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<tr>
<td>Tensile properties of linear low density polyethylene (LLDPE) / recycled acrylonitrile butadiene rubber (NBRr) / rice husk powder (RHP) composites</td>
<td>Plastic composite</td>
<td>LLDPE</td>
<td></td>
<td>Tensile strength of composite decreased with increase of NBRr but elongation at break increased. Tensile strength &amp; elongation at break for composites with ENR-50 increased.</td>
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<td>Rheological properties of RLDPE/LLDPE blends</td>
<td>Plastic composite</td>
<td>LDPE, LLDPE</td>
<td>100%</td>
<td>Blends of recycled and virgin LDPE &amp; LLDPE showed potential successes</td>
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<tr>
<td>Improved mechanical properties of recycled linear low-density polyethylene composites filled with date palm wood powder</td>
<td>Plastic composite</td>
<td>LLDPE</td>
<td></td>
<td>Adding date palm wood powder to recycled LLDPE increased flexural strength of composites by 1.5 times. Water uptake was partially suppressed with addition of powder</td>
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<td>Use of coir-filled LLDPE as a reinforcement for natural rubber composite</td>
<td>Rubber composite</td>
<td>LLDPE</td>
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<td>Coir and LLDPE mixture had better compatibility with natural rubber than just the unmodified coir. Modified coir also showed greater storage modulus and lower tan delta</td>
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<td>Mechanical, thermal and morphological characterization of recycled LDPE/corn starch blends</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Recycled LDPE/corn starch blend reduced MFI values, tensile strength, and elongation at break but increased modulus</td>
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<td>Low-density polyethylene waste/recycled wood composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>LDPE from packaging film mixed with pine wood waste (PWW) and maleic anhydride grafted polyethylene. PWW amount can be adjusted to get different mechanical properties for different applications</td>
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<tr>
<td>Flat-pressed wood plastic composites from sawdust and recycled polyethylene</td>
<td>Plastic composite</td>
<td>PET</td>
<td></td>
<td>Wood plastic composite's density, moisture content, water absorption, thickness swelling, and mechanical properties measured. Density decreased when sawdust content increased. Water absorption and thickness swelling increased when PET content decreased</td>
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<td>terephthalate: Physical and mechanical properties</td>
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<tr>
<td>Characterization of wood plastic composites manufactured from recycled plastic</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Used samples of construction plastic waste and municipal mixed plastic waste and tested for flexural, tensile, and un-notched impact strength, hardness properties, and water absorption. Found samples had lower strength, comparable hardness, and higher stiffness than virgin LDPE</td>
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<td>blends</td>
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<td>Rice husk filled polymer composites</td>
<td>Plastic composite</td>
<td>LDPE, HDPE, PLA, PP,</td>
<td></td>
<td>Rice husk (RH) added to polymer composites increases biodegradability, toughness, resistance to weathering, makes the composites cheaper and more light weight. Gives composite a higher resistance to termite and ability to deal with moisture compared to wood based composites</td>
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<td>composites</td>
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<td>PVC</td>
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<tr>
<td>Effect of recycled materials on the properties of wood fiber-polyethylene</td>
<td>Plastic composite</td>
<td>LDPE, LLDPE, PP</td>
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<td>Contact angles increased with addition of Epolene E-43, then decreased as concentrations of urea formaldehyde (UF), phenol formaldehyde (PF), and isocyanate (ISO) increased. Contact angle ratings for different plastic types followed the sequences of PP &gt; LLDPE &gt; LDPE and distilled water &gt; UF &gt; PF &gt; ISO</td>
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<td>composites - Part 2</td>
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<td>Properties of recycled LDPE/Birch fibre composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
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<td>LDPE reinforced with yellow birch fibre was put through simulation of recycling. Results showed polymer crystallinity increased with number of composite regeneration while zero-shear viscosity decreased with recycling.</td>
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<td>The effects of bamboo powder on some mechanical properties of recycled low-density polyethylene (RLDPE) composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>LDPE mixed with bamboo powder (BP) had a decreased water sorption level, increased flame retardancy, and slight increase in the specific gravity of the composites. Tensile strength and elongation at break decreased with increased filler loading for composites</td>
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<td>Utilization of maise husk/recycled low density polyethylene waste materials for composite board production</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Study found that adding maize husk to RLDPE improved compressive strength of the composite. Thermogravimetric analysis gave a max decomposition temp of 463°C.</td>
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<td>Chitosan filled recycled low-density polyethylene composite: Melt flow behavior and thermal degradation properties</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>LDPE mixed with chitosan and coupling agent ultraplus TP01. Melt flow index values decreased with increasing chitosan but increased with rise of temp. When Ultraplus TP01 was added, MFI values decreased. Thermal stability was reduced with increase of chitosan but increased with addition of ultraplus TP01</td>
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<td>Valorization of recycled LDPE by MMT Nanocomposite</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>LDPE reinforced with nanoclay montmorillonite (MMT) had increased mechanical strength, thermal stability, and sorption, especially for recycled matrix. Recycled composites presented 15% eco-efficiency increase in comparison to virgin composites</td>
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<td>The impact of recycled raw materials on the properties of wood-plastic composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Studied various wood-plastic composites and found improvements in moisture resistance and impact strength and decreased price in various composites</td>
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<tr>
<td>Effects of recycled materials on the properties of wood fiber-polyethylene composites - part 2</td>
<td>Plastic composite</td>
<td>LDPE, LLDPE, PP</td>
<td></td>
<td>Study looked at effects of a compatibilizer on the wettability of birch plywood and polyolefins. Found contact angles increased with addition of Epolene E-43 and decreased as concentrations increased for urea formaldehyde (UF), phenol formaldehyde (PF), and isocyanate (ISO).</td>
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<tr>
<td>Recycling of polyethylene into strong and tough earth-based composite building materials</td>
<td>Building blocks</td>
<td>PE</td>
<td>0-30%</td>
<td>PE waste used as reinforcement in laterite bricks. Composite with 20 vol % of PE had best combination of flexural/compressive strength and fracture toughness</td>
<td></td>
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<tr>
<td>Effects of reinforcement loading on physical and mechanical properties of developed recycling low density polyethylene/maize cob ash particulate (PLDP/MCAp) composite</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td>75-80%</td>
<td>Physical and mechanical properties such as hardness values, density, young's modulus, flexural strength and impact energy increase with a maize cob ash particulate up to 20-25 wt % MCAp then decrease</td>
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<td>Strength and sorption properties of bamboo (bambusa vulgaris) wood-plastic composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Tested three levels of plastic/fibre mixing ratios (1:1, 2:1, 3:1). Results found that as plastic/fibre mixing ratio and board density increased the tensile strength, MOE and MOR increased and TS and WA decreased</td>
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<tr>
<td>Article Title</td>
<td>Product application</td>
<td>Recycled plastics used</td>
<td>Percentage of recycled materials used</td>
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<tr>
<td>Mechanical properties of chemically treated sawdust-reinforced recycled polyethylene composites</td>
<td>Plastic composite</td>
<td>PE</td>
<td></td>
<td>Sawdust treated with cetyltrimethylammonium bromide (CTAB) was used to reinforce recycled PE composites. Treated composites had higher tensile strength and improved young's modulus, flexural strength, flexural modulus, and hardness values compared to untreated composites</td>
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<tr>
<td>Tensile properties of glass fibre reinforced recycled mixed plastic composites</td>
<td>Plastic composite</td>
<td>HDPE, LDPE, PP</td>
<td>70-90 wt %</td>
<td>Recycled HDPE, LDPE, and PP were blended and reinforced with short glass fibre at 10-30 wt%. Tensile strength and modulus increased with glass fibre but composite became brittle and ductility was reduced</td>
<td></td>
</tr>
<tr>
<td>Recycling of plastic solid waste: A state of art review and future applications</td>
<td>Plastic composite</td>
<td>HDPE, LDPE</td>
<td></td>
<td>Paper reviews recycling processes and blending virgin and recycled HDPE/LDPE/Nylon PSW with various reinforcements such as sand, natural fibers, hemp fibers, and metal powder</td>
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</tr>
<tr>
<td>Fabricating and tensile characteristics of recycled composite materials</td>
<td>Plastic composite</td>
<td>HDPE, LDPE, PP</td>
<td>20% LDPE, 4% HDPE, 25% PP (one example)</td>
<td>Composite blend indicated to the left had improved tensile stress</td>
<td></td>
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<tr>
<td>Mechanical properties: wood lumber versus plastic lumber and thermoplastic composites</td>
<td>Plastic composite</td>
<td>HDPE, LDPE, PP, ABS</td>
<td></td>
<td>Study compares modulus of elasticity and the flexural, compressive, tensile, and shear strengths of plastic lumber and wood lumber</td>
<td></td>
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<tr>
<td>Rheological and mechanical properties of composites made from wood flour and recycled LDPE/HDPE blend</td>
<td>Plastic composite</td>
<td>LDPE, HDPE</td>
<td></td>
<td>Studied composites of LDPE and HDPE with wood flour. Found that melt pre-mixing of recycled LDPE/HDPE improved mechanical properties of the wood-plastic composite</td>
<td></td>
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<tr>
<td>Physico-mechanical properties of recycled polyethylene composites reinforced with chemically treated sawdust</td>
<td>Plastic composite</td>
<td>LDPE, HDPE, PE</td>
<td>65-80%</td>
<td>Sample with sawdust treated with NaOH+Surfactant had better mechanical properties and greater resistance to water absorption. Recycled PE matrix-based composites had excellent durability and mechanical properties compared to virgin plastics</td>
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<tr>
<td>Effect of elevated temperature on the tensile properties of recycled mixed plastic waste</td>
<td>Plastic composite</td>
<td>LDPE, HDPE, PP</td>
<td></td>
<td>Study found thermal stability of mixed recycled plastics similar to virgin plastics. Tensile strength and modulus reduced when temp increased from 23C to 100C. Higher reduction of tensile modulus than tensile strength at higher temp</td>
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<tr>
<td>Utilization of rice husk as reinforcement in plastic composites fabrication - a review</td>
<td>Plastic composite</td>
<td>LDPE, PP</td>
<td></td>
<td>PP/Rice Husk (RH) composite had decreased stress at peak and increased tensile modulus and modulus in flexure. LDPE/RH composite had low strength, high stiffness, and high hardness</td>
<td></td>
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<tr>
<td>Glass fibre and recycled mixed plastic wastes: recent developments and applications</td>
<td>Plastic composite</td>
<td>LDPE, HDPE, PVC, PET, PP</td>
<td></td>
<td>Composites with glass fibre added have high stiffness and strength and reduced ductility</td>
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<tr>
<td>Effects of raw materials on the properties of wood fiber-polyethylene composites - Part 3: Effect of a compatibilizer and wood adhesive on the interfacial adhesion of wood/plastic composites</td>
<td>Wood plastic composite</td>
<td>LDPE, LLDPE, PP</td>
<td></td>
<td>ISO-bonded LDPE had highest interfacial shear strength compared to other LDPE composites. Addition of E-43 increased interfacial shear strength for all plastic except ISO-bonded LDPE and LLDPE. LDPE and LLDPE composites experienced adhesive failure and PP composites had cohesive failure</td>
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<tr>
<td><strong>Comparative study of the morphology and properties of PP/LLDPE/wood powder and MAPP/LLDPE/wood powder blend composites</strong></td>
<td>Wood plastic composite</td>
<td>LLDPE, PP</td>
<td>90-70 wt %</td>
<td>MAPP/LLDPE had better mechanical and thermal properties than the PP/LLDPE blend because of a stronger interfacial interaction between MAPP, LLDPE, &amp; wood powder (WP). MAPP/LLDPE blend was also more thermally stable than the PP/LLDPE blend</td>
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<tr>
<td><strong>Microfibrillar reinforced composites from PET/LDPE blends: Morphology and mechanical properties</strong></td>
<td>Plastic composite</td>
<td>LDPE, PET</td>
<td>LDPE at 50 and 70 wt %</td>
<td>LDPE was reinforced by microfibrils of PET and found the elastic modulus 10x higher than plain LDPE and 3x higher than LDPE reinforced with glass spheres. Tensile strength at least 2x higher than plain LDPE or LDPE reinforced with glass spheres</td>
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<tr>
<td><strong>Composite of low-density polyethylene and aluminum obtained from the recycling of postconsumer aseptic packaging</strong></td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Composite of LDPE and PEAL (aluminum composite) had higher thermooxidative stability, higher crystallinity, lower impact resistance, and higher tensile strength than other olefin polymers</td>
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<tr>
<td><strong>Silane-crosslinking of recycled low-density polyethylene/wood composites</strong></td>
<td>Wood plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Studied silane-crosslinking of recycled LDPE wood composites. Crosslinked composite strength, toughness, and creep resistance were improved compared to uncrosslinked composites. Flexural strength was doubled compared to uncrosslinked samples</td>
<td></td>
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<tr>
<td><strong>Influence of thermoplastic elastomers on adhesion in polyethylene-wood flour composites</strong></td>
<td>Wood plastic composite</td>
<td>LDPE</td>
<td></td>
<td>rLDPE/wood flour mix had SEBS-MA added as compatibilizer. Tensile strength reached max at 4wt% SEBS-MA content. SEBS-MA improved impact strength and elongation at break but decreased stiffness</td>
<td></td>
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<tr>
<td>Influence of processing conditions on the tensile properties of unidirectional UHMWPE fibre/LDPE composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Tensile strength decreased but tensile modulus was not strongly affected.</td>
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<tr>
<td>Effect of ageing on the physical and mechanical properties of sisal-fiber-reinforced polyethylene composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>LDPE/sisal composites with and without addition of cardanol derivative of toluene diisocyanate (CTDIC). Composites treated with CTDIC showed superior mechanical properties and better dimensional stability compared to untreated composites</td>
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<tr>
<td>Laboratory design and investigation of the properties of continuously graded asphaltic concrete containing recycled plastics aggregate replacement (Plastiphalt)</td>
<td>Concrete composite</td>
<td>LDPE</td>
<td></td>
<td>Study found the compacted Plastiphalt mix has lower bulk density than conventional control mix. A 30% aggregate replacement with LDPE reduces density by 16%. LDPE replacement also results in a 250% increase in the Marshall stability value and an improved Marshall quotient value.</td>
<td></td>
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<tr>
<td>Short pineapple-leaf-fiber-reinforced low-density polyethylene composites</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Composites of short pineapple-leaf-fiber (PALF) reinforced LDPE were made with melt-mixing and solution-mixing methods. Solution-mixed composites had better tensile properties than melt-mixed. Composite performed better than other cellulose-fiber-reinforced LDPE composites</td>
<td></td>
</tr>
<tr>
<td>Properties of low-density polyethylene/palm kernel shell composites: Effect of polyethylene co-acrylic acid</td>
<td>Plastic composite</td>
<td>LDPE</td>
<td></td>
<td>Study found that increasing palm kernel shell (PKS) decreased tensile strength and elongation at break but Young's modulus and water absorption of composites increased</td>
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</table>
### Performance of polyolefin composites containing recycled paper fibers

<table>
<thead>
<tr>
<th>Article Title</th>
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<th>Recycled plastics used</th>
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</tr>
</thead>
<tbody>
<tr>
<td>FDA approves post-consumer PP for reusable packaging</td>
<td>Reusable crates &amp; pallets</td>
<td>LDPE, PP</td>
<td>100</td>
<td>Strict source control, low likelihood of contaminants in recycled PP/LDPE blend</td>
<td></td>
</tr>
<tr>
<td>Can plastic roads help save the planet?</td>
<td>Asphalt</td>
<td>PE</td>
<td></td>
<td>Recycled plastic replaces bitumen as the binding agent in asphalt</td>
<td></td>
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<tr>
<td>MIT students fortify concrete by adding recycled plastic</td>
<td>Concrete</td>
<td>polyethylene terephthalate</td>
<td>1.5%</td>
<td>Reducing CO2 emissions from concrete production by using recycled plastics. Also makes cement stronger</td>
<td>Requires additive of fly ash to produce a stronger concrete</td>
</tr>
<tr>
<td>Recycler rescues forage bags from landfills</td>
<td>Can liners</td>
<td>LDPE</td>
<td>100%</td>
<td>Diverts ag bags from landfill; Revolution Bags have a closed loop system</td>
<td>Requires washing ag bags</td>
</tr>
<tr>
<td>Closing the cycle of plastic: Decent housing solutions from recycled plastics</td>
<td>Plastic bricks</td>
<td>PP, LDPE, HDPE, PET, PS, HIPS, ABS, PC</td>
<td>100%</td>
<td>Water resistant, combustion resistant, durable, immune to insects/microorganisms, insulates well, economically competitive</td>
<td></td>
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<tr>
<td>This Japanese invention can recycle plastic into oil</td>
<td>Oil/Fuel</td>
<td>PE, polystyrene (PS), polypropylene (PP)</td>
<td>100%</td>
<td>1kg of plastic can be converted into 1 liter of oil with 1 kWh of electricity, made for household use</td>
<td>Made for household use and end product is oil</td>
</tr>
<tr>
<td>One use for post-consumer plastic film: agricultural irrigation</td>
<td>Irrigation piping</td>
<td>LDPE</td>
<td>100%</td>
<td>Better than previously used metal because this does not corrode, is cheaper, doesn't have to be perfect in appearance</td>
<td></td>
</tr>
<tr>
<td>100% Film made from post-consumer waste: A challenging application</td>
<td>Plastic film</td>
<td>LDPE</td>
<td>100%</td>
<td>Produces a good film once contaminants have been sorted out</td>
<td>Lots of contaminants, plastics must be washed first</td>
</tr>
<tr>
<td>From consumer to supplier: Trex has begun producing recycled LLDPE pellets for commercial sale</td>
<td>Drip irrigation tape, trash bins, blown film, trash bags, ag film, garden products, composite lumber</td>
<td>LLDPE</td>
<td>100%</td>
<td>Company already produces consistent, cost-effective LLDPE pellets, hoping to expand use for post-consumer plastics</td>
<td></td>
</tr>
<tr>
<td>Post-consumer waste becomes high-quality film and Poligroup's new model plant</td>
<td>Plastic film</td>
<td>LDPE, LLDPE</td>
<td>100%</td>
<td>Uses ag LDPE film, LLDPE film from bale wrapping, and film from household waste. End product is high quality, thin film and is inexpensive to produce</td>
<td>Requires human sorting and washing step.</td>
</tr>
<tr>
<td>Ultra-Post Reusable T-Shirt Bags</td>
<td>Plastic bags</td>
<td>LDPE</td>
<td>20%</td>
<td>Is 100% recyclable</td>
<td></td>
</tr>
<tr>
<td>Plastics that can be recycled for 3D printing</td>
<td>3-D Printing</td>
<td>LDPE</td>
<td>100%</td>
<td>Recycled LDPE resulted a more flexible plastic when 3D printed, could have different applications than traditional plastics used</td>
<td>The shredder was set up for PLA and PS, not LDPE, so there was more work on the front end to prepare the LDPE</td>
</tr>
<tr>
<td>Best recycling ever: turning old plastic bags into carbon nanotubes</td>
<td>Carbon nanotubes</td>
<td>LDPE, HDPE</td>
<td></td>
<td>The added catalyst (cobalt particles) makes the nanotubes suitable for use in lithium-air batteries, which is viewed as an asset</td>
<td>Had to add large amounts of catalyst for the process to work</td>
</tr>
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<tr>
<td><strong>Composite decking leader repurposes its recycled plastic into polyethylene pellets</strong></td>
<td>Plastic pellets</td>
<td>LLDPE</td>
<td></td>
<td>Ideal for use of: trash bags, bins, totes, kayaks. Uses Trex's leftover material from wood composite deck building</td>
<td></td>
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<tr>
<td><strong>Plastic Lumber Possibilities</strong></td>
<td>Wood composite</td>
<td>PE, PP</td>
<td></td>
<td>More durable, stable, resilient, and resistant to weather, rot, mildew, and termites. Don't require repainting or restaining - are low maintenance</td>
<td>Viscoelasticity is main limitation. Time and temperature can cause “creeping” or permanent deformation over time</td>
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<tr>
<td><strong>Roads made of plastic waste in India? Yes! Meet the professor who pioneered the technique</strong></td>
<td>Cement additive, plastic brick (plastone)</td>
<td>LDPE, PE</td>
<td></td>
<td>Reduces plastic waste and bitumen use for paving roads. Process requires no new machinery. Increases durability of roads</td>
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<tr>
<td><strong>You can make concrete 20% stronger by adding recycled plastic in &amp; also save the environment</strong></td>
<td>Concrete composite</td>
<td>PE</td>
<td></td>
<td>Recycled plastic treated with gamma radiation made cement 20% stronger than normal with no negative side effects</td>
<td></td>
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<tr>
<td><strong>In with recycled plastic bricks, out with cement</strong></td>
<td>polymer concrete bricks</td>
<td>PE</td>
<td></td>
<td>Polymer concrete absorbs less water so is better for freezing temperatures, is also less expensive to create than traditional bricks</td>
<td></td>
</tr>
<tr>
<td><strong>Old plastic bags become bricks in Indian houses</strong></td>
<td>Plastic bricks</td>
<td>Soft plastic - plastic bags and foil-covered snack bags</td>
<td>100%</td>
<td>Bricks can withstand up to 6 tons of pressure and very durable. Can withstand monsoon season and the creator is working on a way to create bricks without electricity so that rural areas can create them</td>
<td></td>
</tr>
<tr>
<td><strong>Plastic bags as building blocks</strong></td>
<td>Plastic bricks</td>
<td>Plastic bags</td>
<td>100%</td>
<td>Easy to create, requires no additives, and is cost-effective when compared to cement or ordinary bricks.</td>
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<tr>
<td>This neighborhood recycling lab turns plastic into building blocks to make the neighborhood better</td>
<td>Plastic bricks</td>
<td>Plastic bags</td>
<td>100%</td>
<td>Increases recycling, decreases waste, educates the public, produces a durable brick</td>
<td></td>
</tr>
<tr>
<td>Bricks from recycled plastic</td>
<td>Plastic bricks</td>
<td>PET</td>
<td>100%</td>
<td>Structurally sound enough to withstand earthquakes and typhoons, relatively cheap, and sustainable</td>
<td></td>
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<tr>
<td>ByFusion: Creating the building blocks for tackling ocean waste</td>
<td>Plastic bricks</td>
<td>All plastic except polystyrene</td>
<td>100%</td>
<td>Structurally sound, cheap to create, uses a wide variety of plastic, uses a non-toxic manufacturing process</td>
<td></td>
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<tr>
<td>JCU Team wins innovation award for 'green' concrete</td>
<td>Concrete composite</td>
<td>PP</td>
<td></td>
<td>LCA shows production with recycled plastic produces 90% less CO2 than using steel mesh in concrete and plastic fibers are equivalent in strength</td>
<td></td>
</tr>
<tr>
<td>Plastic and UAE Sand are building block of new brick</td>
<td>Plastic bricks</td>
<td>Plastic waste</td>
<td>30%</td>
<td>Uses unsorted and uncleaned plastic waste. Is resistant to oils, acid, salts and alkalis. Is 30% lighter than concrete, insulates against heat &amp; cold, is flame-resistant and water-resistant. It costs 50% less to manufacture than concrete</td>
<td></td>
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<tr>
<td>Kiwi company turns plastic waste into high-quality concrete</td>
<td>Concrete composite</td>
<td>Plastic waste</td>
<td></td>
<td>Don't need to clean the plastic. End product is 10-40% lighter than plain concrete, would save on transportation costs.</td>
<td></td>
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<tr>
<td>Sustainable building materials for low-cost housing</td>
<td>Plastic bricks</td>
<td>Polypropylene</td>
<td></td>
<td>Bricks made of polypropylene and rice husks. Bricks are fire resistant, provide heat and sound insulation, are waterproof and lightweight.</td>
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<tr>
<td><strong>Lightweight plastic panels manufactured from recycled plastics - panels for commercial vehicles and other applications</strong></td>
<td>Plastic panels</td>
<td>PP, PET, PE, LDPE</td>
<td></td>
<td>Panels are much lighter, will save fuel costs and reduce CO2 emissions in transportation. Has applications in insulation, acoustic and impact resistance, caravans, portable cabins, staging, decking, and flooring.</td>
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<tr>
<td><strong>High strength wood plastic composites recycled from construction and demolition wood waste</strong></td>
<td>Plastic composite</td>
<td>PE, PP</td>
<td></td>
<td>Company evaluated recycled wood plastic composite boards</td>
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**Additional HDPE Applications**

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<tr>
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<tbody>
<tr>
<td>Scholarly</td>
<td>Use of post-consumer waste plastics in cement-based composites</td>
<td>Cement</td>
<td>HDPE</td>
<td>0-5%</td>
<td>Increased performance of concrete's compressive strengths</td>
<td>Low percentage recycled material</td>
</tr>
<tr>
<td>Scholarly</td>
<td>Diversion from landfill: quality products from valuable plastics</td>
<td>blow-molded bottle</td>
<td>HDPE</td>
<td>100%</td>
<td>Properties of 100% post-consumer HDPE exceeded materials specifications for virgin plastic designs</td>
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<tr>
<td>Scholarly</td>
<td>Performance of Corrugated HDPE Pipes Manufactured with Recycled Content 1 Underneath Commuter Railroads</td>
<td>Corrugated drainage pipe</td>
<td>HDPE</td>
<td></td>
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<tr>
<td>Scholarly</td>
<td>Development of a recycled polymer modified binder for use in stone mastic asphalt</td>
<td>Asphalt</td>
<td>HDPE</td>
<td>4%</td>
<td>Out-performs traditional binders in stone mastic asphalt</td>
<td>Low percentage plastic</td>
</tr>
<tr>
<td>Scholarly</td>
<td>Suitability of recycled HDPE for 3D printing filament</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
<td>Found it comparable to ABS and PLA</td>
<td></td>
</tr>
<tr>
<td>Scholarly</td>
<td>Plastic container made from a fusion blend of post-consumer plastic and ethylene polymers</td>
<td>Plastic container</td>
<td>HDPE</td>
<td>25 - 95%</td>
<td>Better crack resistance than usual when working with post-consumer resins</td>
<td>Blend of virgin and recycled HDPE and virgin LDPE</td>
</tr>
<tr>
<td>Scholarly</td>
<td>Life cycle analysis of distributed recycling of post-consumer high density polyethylene for 3-D printing filament</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
<td>Recycling &amp; 3-D printing method for low-density population centers or at home</td>
<td></td>
</tr>
<tr>
<td>Scholarly</td>
<td>Feasibility study of use of recycled high-density polyethylene and multi response optimization of injection molding parameters using combined grey relational and principal component analyses</td>
<td>Trays</td>
<td>HDPE</td>
<td>100%</td>
<td>Tensile, compressive, and flexural strengths of recycled HDPE are very close to virgin HDPE - is a good substitute</td>
<td>Requires maleated polypropylene at 3-5% to help with stability and mechanical properties</td>
</tr>
<tr>
<td>Scholarly</td>
<td>Dimensional stability and mechanical behavior of wood-plastic composites based on recycled and virgin high-density polyethylene</td>
<td>Wood plastic composites</td>
<td>HDPE</td>
<td></td>
<td>recycled HDPE had equivalent tensile and flexural properties as virgin HDPE and, when added to wood, improved stability and strength</td>
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<tr>
<td>Article Type</td>
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<td>Recycled plastics used</td>
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<tr>
<td>News</td>
<td>PE Recycled Fix-Corp to Begin Making Pallets</td>
<td>Plastic pallets</td>
<td>HDPE</td>
<td>100%</td>
<td>Uses recycled HDPE from their own recycling plant, already has infrastructure in place</td>
<td></td>
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<tr>
<td>News</td>
<td>Study: Pipe with recycled HDPE good for rail uses</td>
<td>Corrugated drainage pipe</td>
<td>HDPE</td>
<td>49%</td>
<td>Study showed no discernible differences in performance of the recycled HDPE pipe vs the virgin HDPE pipe after 3 years</td>
<td></td>
</tr>
<tr>
<td>Scholarly</td>
<td>Correlation of rheological and mechanical properties for blends of recycled HDPE and virgin polyolefins</td>
<td>Polymer blend</td>
<td>HDPE</td>
<td>80%</td>
<td>Studied rheological and mechanical properties for different blends of recycled HDPE and virgin polyolefins</td>
<td></td>
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<tr>
<td>Scholarly</td>
<td>Study on mechanical properties of recycled HDPE/Waste rubber powder blends</td>
<td>Polymer blend</td>
<td>HDPE</td>
<td>80%</td>
<td>When blend was at 80% recycled HDPE and 20% waste rubber powder it had the best mechanical properties</td>
<td></td>
</tr>
<tr>
<td>Scholarly</td>
<td>A review on tertiary recycling of high-density polyethylene to fuel</td>
<td>Fuel</td>
<td>HDPE</td>
<td>100%</td>
<td></td>
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<tr>
<td>Scholarly</td>
<td>Characteristics of wood-fiber plastic composites made of recycled materials</td>
<td>Wood fiber composite</td>
<td>HDPE</td>
<td></td>
<td>Composites with recycled HDPE had superior properties</td>
<td></td>
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<tr>
<td>News</td>
<td>Large scale HDPE recycling trial</td>
<td>Plastic milk bottles</td>
<td>HDPE</td>
<td>30%</td>
<td>Recycled HDPE performs exactly the same as virgin HDPE, meaning no new equipment is required except blending equipment</td>
<td></td>
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<tr>
<td>News</td>
<td>Study shows strength of HDPE pipe with recycled resin</td>
<td>Corrugated pipe</td>
<td>HDPE</td>
<td>49%</td>
<td>Pipe with 49% recycled HDPE performed exactly the same as pipe with 100% virgin material installed at same time and had same expected lifetime of 100+ years</td>
<td></td>
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<tr>
<td>News</td>
<td>Porous Paving System</td>
<td>Pavers</td>
<td>HDPE</td>
<td>100%</td>
<td>Pavers have long-term durability</td>
<td></td>
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<tr>
<td>News</td>
<td>Letting the rain fall through</td>
<td>Pavers</td>
<td>HDPE</td>
<td></td>
<td>Pavers are durable and can withstand consistent traffic, abrupt braking/acceleration, and slightly sloped surfaces</td>
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<tr>
<td>News</td>
<td>Cornfield tiled and planted in one day</td>
<td>Corrugated pipe</td>
<td>HDPE</td>
<td>50%+</td>
<td>Has long service life and is resistant to cracking. HDPE is a versatile material and can be created into any perforation pattern without diminishing performance or longevity. Is also more resistant to frost than concrete pipes</td>
<td></td>
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<tr>
<td>News</td>
<td>Indian company Protoprint transforms waste into 3D printing filament for commercial use</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
<td>Reduces waste and increases local work without compromising filament</td>
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<tr>
<td>News</td>
<td>3D Printing a solution to the major waste disposal crisis in Samoa</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
<td>Reduces waste without compromising filament</td>
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<tr>
<td>Scholarly</td>
<td>Mechanical and morphological properties of recycled high-density polyethylene, filled with calcium carbonate and fly ash</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>HDPE/calcium carbonate/fly ash mixture had improved mechanical properties</td>
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<tr>
<td>News</td>
<td>Got Milk? Then you've got 3D printer filament at a 99.7% discount</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
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<td>Scholarly</td>
<td>Mobile open-source solar-powered 3-D printers for distributed manufacturing in off grid communities</td>
<td>3-D Printing filament</td>
<td>HDPE</td>
<td>100%</td>
<td>Analyzes RepRap technology and rural applications</td>
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<tr>
<td>Scholarly</td>
<td>Mechanical properties of wood-plastic composite (WPC) made of recycled high-density polyethylene (HDPE) and recycled wood flour (RWF)</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>Looks at mechanical properties of HDPE and recycled wood flour composite</td>
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<tr>
<td>Scholarly</td>
<td>The impact of plastics virginity on water absorption and thickness swelling of wood plastic composites</td>
<td>Plastic composite</td>
<td>HDPE, PP</td>
<td>50%, 75%</td>
<td>Compared adding wood flour to HDPE &amp; PP in different weights. Water absorption and thickness swelling of composites with PP was lower than with HDPE. Composite with 50% wood flour and 50% HDPE had maximum moisture sorption.</td>
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<tr>
<td>Scholarly</td>
<td>Properties of wood plastic composites made of recycled HDPE and wood flour from CCA-treated wood removed from service</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td>50%</td>
<td>HDPE and CCA-treated wood samples had higher flexural bending properties compared to composites with virgin pine or recycled urea formaldehyde bonded particleboard. Composite also had higher modulus of elasticity and modulus of rupture.</td>
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<tr>
<td>Scholarly</td>
<td>Development of recycled plastic composites from consumer electronic appliances</td>
<td>Plastic composite</td>
<td>HDPE, ABS, PS, PC</td>
<td></td>
<td>PC-ABS-HDPE blend had highest modulus value and withstood most stress and strain of any other composite tested.</td>
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<tr>
<td>Scholarly</td>
<td>Outstanding impact resistance of post-consumer HDPE/multilayer packaging composites</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>Blend of HDPE, PET, PE, and aluminum was found to have higher tensile impact strength and elasticity compared to pure polyethylene.</td>
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<tr>
<td>Scholarly</td>
<td>Dynamic mechanical and thermal properties of MAPE treated jute/HDPE composites</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>Tensile, flexural, and impact strengths increased with the increase in jute fibre content up to 30% - higher than that caused a deterioration in mechanical strength. Composites treated with MAPE showed improved properties vs. untreated composite.</td>
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<tr>
<td>Scholarly</td>
<td>Effect of nanographene on physical, mechanical, and thermal properties and morphology of nanocomposite made of recycled high-density polyethylene and wood flour</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td>70%</td>
<td>Study found that by increasing nanographene up to 0.5% by weight, flexural strength, flexural modulus, and notched impact strength of composite increased. At 2.5 wt% nanographene these properties reduced.</td>
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<tr>
<td>Scholarly</td>
<td>Study of wood-plastic composites with reused high-density polyethylene and wood sawdust</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>HDPE/sawdust composite had low plastic strain and improved mechanical responses including modulus and maximum stress</td>
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<tr>
<td>Scholarly</td>
<td>Preparation and properties of wood plastic composites made of recycled high-density polyethylene</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td>15, 30, and 45 wt%</td>
<td>Study found addition of polyethylene-grafted maleic anhydride (PE-g-MA) improved compatibility between recycled HDPE and poplar fibers. PE-g-MA also improved stability and mechanical properties and tensile strength.</td>
<td></td>
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<tr>
<td>Scholarly</td>
<td>Extruded bagasse fiber plastic composites: creep performance</td>
<td>Plastic composite</td>
<td>HDPE, PVC</td>
<td></td>
<td>HDPE/bagasse composites creep more compared to PVC and PP composites</td>
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<tr>
<td>Scholarly</td>
<td>Fly ash in optimized composites based on recycled plastics and rubber</td>
<td>Plastic composite</td>
<td>HDPE, PET</td>
<td>35 wt% HDPE, 5 wt% PET</td>
<td>0.25 wt% fly ash addition to the composites increased compression resistance by 3x. Composites with fly ash also have non-wetting behavior and dense surface structure</td>
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<tr>
<td>Scholarly</td>
<td>Development of wood flour-recycled polymer composite panels as building materials</td>
<td>Plastic composite</td>
<td>HDPE, PP</td>
<td></td>
<td>rHDPE and rPP mixed with sawdust and HDPE and PP mixed with sawdust were tested. Recycled composites had excellent dimensional stability &amp; mechanical properties compared to virgin samples</td>
<td></td>
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<tr>
<td>Scholarly</td>
<td>Rheological properties of HDPE/chitosan composites modified with PE-g-MA</td>
<td>Plastic composite</td>
<td>HDPE</td>
<td></td>
<td>Presence of chitosan increases complex viscosity, loss modulus, storage modulus and torque. PE-g-MA increased matrix-filler interactions and acted as an effective compatibilizer</td>
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<tr>
<td>Scholarly</td>
<td>A mechanical analysis on recycled PET/HDPE composites</td>
<td>Plastic composite</td>
<td>HDPE, PET</td>
<td></td>
<td>Studied the stiffness and machinability of PET/HDPE blend, found good performance for compression and machinability</td>
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<td><strong>Mechanical properties of composites from sawdust and recycled plastics</strong></td>
<td>Plastic composite</td>
<td>HDPE, PP</td>
<td></td>
<td>Studied mechanical properties of wood plastic composites made from virgin and recycled HDPE or PP and sawdust. Composites with PP had higher stiffness and strength than HDPE composites but lower unnotched impact strength. Mechanical properties of composites with recycled plastics were comparable to ones with virgin plastic</td>
<td></td>
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</table>