Recycled Filament Datasheets

Mechanical, Thermal, and Processing Properties

for NASA-Compatible Additive Manufacturing

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This document compiles the technical datasheets of post-recycled materials and composite filaments suitable for additive manufacturing within NASA's In-Situ Resource Utilization (ISRU) framework. Each section presents recycling viability, processing methods, mechanical performance, and recommended printing parameters for Mars habitat applications.

Contents

Overview

This compilation details recycled materials adapted for NASA's Refabricator and Recycler additive manufacturing systems. Each datasheet includes:

– Material viability and ISRU potential.

– Step-by-step recycling processes.

– 3D-printing parameter tables.

– Mechanical and thermal property ranges.

– Recommended applications and compositions.

1. Recycled Fabric Waste (Cotton, Cellulose, Nylon, Polyester) → CNC-Reinforced Filament

1.1. Viability

– Highly feasible due to the abundance of post-consumer textile waste.

– Compatible with NASA's Refabricator, Recycler, and AMF systems.

– Reduces payload mass and energy cost by 30–40 % vs virgin polymers.

– Supports closed-loop circular manufacturing on Mars.

1.2. Recycling Process

1. **Sorting & Cleaning:** Separate cellulosic and synthetic fabrics; wash, dry ¡ 1 % moisture.
2. **Shredding:** Cut to 1–5 mm fragments.
3. **CNC Extraction:** Hydrolyze cotton with 63 % H_2SO_4 (45 °C, 2 h); neutralize, sonicate, dry.
4. **Matrix Prep:** Melt/pelletize rPET or PLA; dry 6–8 h at 55 °C.
5. **Compounding:** Mix PLA/rPET + 0.5–2 wt % CNC in twin-screw extruder.
6. **Filament Extrusion:** Diameter 1.75 ± 0.05 mm; cool and spool under tension.

1.3. Printing Settings

Parameter	**Recommended Setting**
Filament Composition	PLA or rPET reinforced with 0.5–2 wt % CNC
Extruder Temperature	PLA: 205–220 °CrPET: 250–260 °C
Bed Temperature	PLA: 60 °CrPET: 85 °C
Layer Height	0.2 mm
Print Speed	30–45 mm/s
Cooling Rate	40–60 % (after layer 2)
Infill Density	80–100 %
Annealing (optional)	90 °C for 20 min – increases crystallinity and stiffness

Table 1: Printing Settings for CNC-Reinforced Fabric Waste Filament

1.4. Mechanical & Thermal Properties

– Moderate tensile strength increase (+17 % vs pure PLA).

– Improved stiffness and surface finish.

– Good dimensional stability after annealing.

1.5. Recommended Applications

– Tooling & fixtures (clips, brackets, holders).

– Habitat interior components (covers, duct guides).

– Consumables (hinges, handles, fasteners).

1.6. Recommended Filament Composition

– PLA + 1 wt % surface-grafted CNC (from cotton waste).

– High printability, stable extrusion, improved toughness.

2. Recycled High-Density Polyethylene (rHDPE) Reinforced with Glass Fiber

2.1. Viability

– Abundant and easily collected from containers and tools.

– Compatible with Refabricator hardware.

– 60–70 % less energy vs virgin production.

2.2. Recycling Process

1. Sort & Clean (80 °C vacuum-dry 2 h).
2. Grind to 2–5 mm chips.
3. Compound 60 wt % rHDPE + 40 wt % virgin HDPE + 15 wt % E-glass + 5 wt % PE-g-MA (160 °C, 10 min).
4. Pelletize and extrude (230 °C nozzle, 90 °C bed).
5. Anneal 90 °C × 30 min.

2.3. Printing Settings

Parameter	**Recommended Setting**
Nozzle Temperature	230 °C
Bed Temperature	90 °C
Nozzle Diameter	1.0 mm
Layer Height	0.5 mm
Print Speed	20 mm/s
Raster Angle	±45°
Infill Density	100 % (load-bearing parts)
Annealing	90 °C × 30 min – enhances fusion and stiffness

Table 2: Printing Settings for rHDPE-Glass Fiber Composite Filament

2.4. Mechanical & Thermal Properties

– Elastic modulus 760 ± 80 MPa.

– Tensile strength 23–25 MPa.

– Vicat softening point 115 °C.

2.5. Recommended Applications

- Structural panels and housings.
- Containers and rover mounts.

2.6. Recommended Filament Composition

- 60 wt % rHDPE + 40 wt % virgin HDPE + 15 wt % glass fibers + 5 wt % PE-g-MA.

3. Recycled Nylon-6 (Polyamide-6)

3.1. Viability

- High-performance engineering polymer for tools and fabrics.
- Fully compatible with Refabricator systems.
- Up to 55 % energy savings vs virgin nylon.

3.2. Recycling Process

1. Sort & Clean (100 °C dry 3 h).
2. Grind to 2–3 mm flakes.
3. Optional Depolymerization (250–300 °C under N) → -caprolactam repolymerization.
4. Mechanical Recycle (250–260 °C extrusion + 5–10 wt % virgin Nylon-6 or compatibilizer).
5. Optionally reinforce with 10 wt % glass or carbon fibers.
6. Extrude 1.75 mm filament; store dry (¡ 0.02 % moisture).

3.3. Printing Settings

Parameter	**Recommended Setting**
Nozzle Temperature	250–265 °C
Bed Temperature	80–90 °C
Chamber Temperature	60–70 °C
Layer Height	0.2 mm
Print Speed	25–40 mm/s
Cooling Rate	30 %
Infill Density	80–100 %
Dry Before Print	80 °C × 6 h (essential due to hygroscopic nature)

Table 3: Printing Settings for Recycled Nylon-6 Filament

3.4. Mechanical & Thermal Properties

- Tensile strength 60–70 MPa (recycled).
- Young's modulus 1.9–2.4 GPa.
- Heat deflection temperature 165 °C.

3.5. Recommended Applications

- Load-bearing fixtures, brackets, and mechanical housings.
- Rover parts and flexible joints.

3.6. Recommended Filament Composition

- Recycled Nylon-6 + 5 wt % virgin Nylon-6 + 1–3 wt % compatibilizer (+ 10 wt % fiber optional).

4. Recycled Polyester (rPET) from Post-Consumer Textiles and Bottles

4.1. Viability

– Highly feasible and commercially proven.

– Directly compatible with Refabricator and AMF systems.

– Saves 59% energy and 32% CO emissions vs virgin PET.

4.2. Recycling Process

1. Collect and sort PET clothing and packaging; remove contaminants.
2. Clean and dry (80–90 °C × 4 h).
3. Mechanically recycle: shred (3–5 mm), extrude at 250–270 °C, filter, pelletize, dry.
4. Optionally depolymerize to BHET via glycolysis for virgin-grade rPET.

4.3. Printing Settings

Parameter	**Recommended Setting**
Nozzle Temperature	250–260 °C
Bed Temperature	75–85 °C
Layer Height	0.2 mm
Print Speed	35–50 mm/s
Cooling Rate	40–50 %
Infill Density	80–100 %
Dry Before Print	70 °C × 6 h

Table 4: Printing Settings for Recycled Polyester (rPET) Filament

4.4. Mechanical & Thermal Properties

– Tensile strength 45–60 MPa; Elastic modulus 1.8–2.2 GPa.

– Elongation 10–25 %; Tg 75 °C; Tm 255 °C.

4.5. Recommended Applications

– Interior brackets, covers, mounts. Wearables or flexible components.

– Duct joints and storage fixtures within habitats.

4.6. Recommended Filament Composition

– 100 % rPET or 80 % rPET + 20 % virgin PET blend.

5. Recycled Polyethylene Terephthalate (rPET) – ELECTRE Study Variant

5.1. Viability

– Outperforms HDPE and PP in energy efficiency and processability.

– Works within Refabricator (240 °C processing window).

– Retains nearly virgin mechanical properties.

5.2. Recycling Process

1. Collect and sort PET bottles and packaging; remove labels.
2. Wash thoroughly; dry 4–5 h at 160 °C.
3. Shred to 1.75–2.85 mm flakes; extrude at 240–245 °C (5 rpm).
4. Add optional chain extenders (0.5–1 wt %) or fibers (5–10 wt %).

5.3. Printing Settings

Parameter	**Recommended Setting**
Nozzle Temperature	240–245 °C
Bed Temperature	75–85 °C
Layer Height	0.2 mm
Print Speed	35–45 mm/s
Cooling Fan	40–50 %
Infill Density	80–100 %
Dry Before Print	70 °C × 6 h

Table 5: Printing Settings for Recycled PET (ELECTRE Variant) Filament

5.4. Mechanical Properties

– Tensile strength 43.15 MPa (vs 34.87 MPa virgin); Modulus 3346 MPa.

– Hardness 68.7 (Shore D).

5.5. Recommended Applications

– Structural brackets and connectors.

– Containers and protective casings.

5.6. Recommended Filament Composition

- 100 % rPET or rPET + 1–2 wt % chain extender.

6. Recycled Polystyrene (rPS) from Post-Consumer Styrofoam

6.1. Viability

– Lightweight, thermally insulating, and abundant in packaging waste.

– Compatible with Refabricator; low energy demand (240 °C).

6.2. Recycling Process

1. Collect and clean EPS packaging (acetone/ethanol rinse; dry 6–8 h).
2. Dissolve 1 g EPS in 20 mL acetone (30 min stirring).
3. Heat 180–200 °C for 25 min to evaporate solvent and solidify.
4. Extrude 1.75 mm filament; cool and cure 24 h before spooling.

6.3. Printing Settings

Parameter	Recommended Setting
Nozzle Temperature	230–240 °C
Bed Temperature	80–90 °C
Layer Height	0.2 mm
Print Speed	30–40 mm/s
Cooling Fan	30–40 %
Infill Density	80–100 %
Dry Before Print	Ambient or 50 °C × 3 h

Table 6: Printing Settings for Recycled Polystyrene (rPS) Filament

6.4. Mechanical & Thermal Properties

– Density 1.04 g/cm^3; Tensile 20–25 MPa; Modulus 1.4–1.8 GPa.

– Tg 95–100 °C; Thermal conductivity 0.035 W/m·K.

6.5. Recommended Applications

– Thermal insulation panels, non-structural covers, prototype shells.

6.6. Recommended Filament Composition

– 100 % recycled EPS re-extruded at 230–240 °C.

7. Composite Filaments Combining Regolith and Recycled Polymers

7.1. rPET + Regolith Composite

- **Composition:** 80 wt % rPET + 20 wt % basaltic regolith (¡50 µm).
- **Viability:** Basaltic regolith acts as low-cost filler improving compressive strength (+25 %).

Printing Settings:

Parameter	Recommended Setting
Nozzle Temperature	255 °C
Bed Temperature	85 °C
Layer Height	0.2 mm
Print Speed	30 mm/s
Infill Density	100 %

Table 7: Printing Settings for rPET + Regolith Composite Filament

7.2. rHDPE + Regolith Composite

- **Composition:** 70 wt % rHDPE + 30 wt % regolith (¡75 µm) + 2 wt % PE-g-MA.

Printing Settings:

Parameter	Recommended Setting
Nozzle Temperature	230 °C
Bed Temperature	90 °C
Layer Height	0.4 mm
Print Speed	25 mm/s
Infill Density	100 %

Table 8: Printing Settings for rHDPE + Regolith Composite Filament

7.3. rNylon-6 + Basaltic Regolith Composite

- **Composition:** 85 wt % rNylon-6 + 15 wt % basalt microparticles (20 µm).

Printing Settings:

Parameter	Recommended Setting
Nozzle Temperature	255–260 °C
Bed Temperature	90 °C
Chamber Temperature	60 °C
Print Speed	30 mm/s
Infill Density	100 %

Table 9: Printing Settings for rNylon-6 + Basaltic Regolith Composite Filament

7.4. ISRU and Sustainability Considerations

– Regolith reduces Earth-sourced payload mass.

– 15–30 wt % filler gives optimum printability without nozzle clogging.

– Provides reinforcement and thermal mass for habitat structures.

Conclusion

Recycled polymers and regolith-based composites offer a robust foundation for sustainable additive manufacturing on Mars. These datasheets compile viability analyses, recycling workflows, and validated processing parameters for NASA-compatible Refabricator systems within the ISRU framework.

End of Technical Datasheet Compilation
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