To: Genesis Cooperatives
From: Expert Analyst, Circular Economy Division
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Subject: Analysis of 100+ Waste-to-Product Chemical Value Chains

Executive Summary & Methodological Note

This document presents a synthesized analysis of over 100 distinct waste-to-product value chains, derived from scientific literature on circular economy chemical processes. These chains represent tangible opportunities for valorizing common waste streams—including textiles, plastics, e-waste, biomass, and construction debris—into higher-value products through chemical transformation.

Each entry details the required inputs, outputs, processes, technology, and skills. The provided economic estimates for **Startup Cost** and **Potential Monthly Revenue** are illustrative and designed to indicate the potential scale of operation (e.g., pilot, small-to-medium enterprise, industrial). These figures are derived from high-level data points in the reference material (e.g., cost per ton of output, capital estimates for large plants) and should be validated with detailed, market-specific business cases. Profitability in these ventures is often heavily influenced by the acquisition cost of waste feedstock, process efficiency, and local market prices for output products.

The following tables are categorized by primary input material for ease of navigation and strategic planning.

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Waste Valorization Value Chains

1. Textile Waste
These value chains leverage the high cellulose content of cotton and the polymer structures of synthetics like polyester and polyamide.

Value Chain Title	Input Materials	Output Products	Key Chemical Process(es)	Fabrication & Technology Requirements	Required Skills	Estimated Startup Cost (Pilot/SME Scale)	Potential Monthly Revenue (Illustrative)
Cotton Waste to Bioethanol	Post-consumer cotton textiles, cellulosic waste, enzymes, yeast	Bioethanol, residual solids (for biogas/compost)	Pretreatment (shredding), Enzymatic Hydrolysis, Fermentation, Distillation	Shredders, hydrolysis reactors, fermentation tanks, distillation columns	Chemical Engineering, Microbiology, Process Operation, Supply Chain Management	£150,000 - £750,000	£20,000 - £60,000
Cotton Waste to Glucose Syrup	Post-consumer cotton, superconcentrated hydrochloric acid (HCl) or sulfuric acid	Industrial glucose syrup, lignin-like residue	Acid Hydrolysis, Neutralization, Purification	Acid-resistant reactors, filtration systems, neutralization tanks, evaporators	Chemical Engineering, Industrial Chemistry, Safety Management	£100,000 - £500,000	£15,000 - £50,000
Polycotton Waste to PEF Monomers	Polycotton textiles, superconcentrated HCl, catalysts	Glucose, 2,5-Furandicarboxylic acid (FDCA), recovered polyester fiber	Selective Hydrolysis (e.g., Avantium Dawn Technology), Catalytic Conversion	Specialized hydrolysis reactors, catalytic converters, separation units	Organic Chemistry, Catalysis, Chemical Engineering, Polymer Science	£500,000 - £3,000,000	£50,000 - £150,000
Cotton Waste to Cellulose Nanocrystals	Waste cotton fabrics, sulfuric acid, water	Cellulose Nanocrystals (CNC) slurry or powder for high-strength composites	Acid Hydrolysis, Centrifugation, Dialysis, Sonication, Freeze-drying	Glass-lined reactors, high-speed centrifuges, dialysis membranes, sonicators	Materials Science, Nanotechnology, Chemical Engineering	£75,000 -

£350,000 | £10,000 - £40,000 |
Cotton Waste to Aerogels	Waste cotton fibers, polyvinyl alcohol (PVA), glutaraldehyde (GA)	Hydrophobic, insulating aerogel sheets/blocks	Alkali Pretreatment, Gelation (crosslinking), Solvent Exchange, Freeze-drying	Mixers, molds, chemical baths, freeze-dryer or supercritical dryer	Materials Science, Polymer Chemistry, Process Engineering	£50,000 - £250,000	£8,000 - £30,000
Polyester (PET) Waste to rPET Pellets	Post-consumer PET textiles, ethylene glycol	Bis(2-hydroxyethyl) terephthalate (BHET) monomer, recycled PET (rPET) pellets	Glycolysis (Depolymerization), Filtration, Repolymerization	Shredders, heated reactors, vacuum systems, filtration units, pelletizers	Polymer Chemistry, Chemical Engineering, Process Control	£400,000 - £2,500,000	£40,000 - £120,000
Polyester (PET) Waste to TPA Monomer	Post-consumer PET textiles, water, acid/base catalyst	Purified Terephthalic Acid (TPA), Ethylene Glycol (EG)	Hydrolysis (Depolymerization), Crystallization, Purification	High-pressure reactors, crystallizers, filtration and drying equipment	Chemical Engineering, Organic Chemistry, Industrial Separation	£500,000 - £3,000,000	£45,000 - £130,000
Polyamide (Nylon) Waste to Caprolactam	Waste polyamide-6 (PA6) textiles and carpets, catalysts	Caprolactam monomer, amino acid solutions	Catalytic Depolymerization (Hydrolysis/Aminolysis), Distillation	High-temperature reactors, distillation columns, purification systems	Organic Chemistry, Catalysis, Chemical Engineering	£600,000 - £4,000,000	£60,000 - £180,000
Polyamide Waste to Adipic Acid & HMD	Waste polyamide-6,6 (PA66) textiles, strong acids/bases	Adipic acid, Hexamethylenediamine (HMD)	Acid or Base Hydrolysis, Separation, Crystallization	Corrosion-resistant reactors, multi-stage separation units, crystallizers	Industrial Chemistry, Separation Science, Chemical Engineering	£750,000 - £5,000,000	£70,000 - £200,000
Mixed Textile Waste to Wood Adhesives	Mixed unsorted textiles, chemical reagents	Liquid adhesive precursor, solid residues	Solubilization, Chemical Modification, Formulation	Grinders, chemical reactors with high-torque mixers, formulation tanks	Polymer Chemistry, Adhesion Science, Chemical Engineering	£100,000 - £600,000	£15,000 - £45,000
Wool Waste to Keratin Hydrolysate	Waste wool fibers, water, enzymes or alkali	Keratin hydrolysate (for cosmetics, bioplastics), lanolin	Enzymatic or Alkaline Hydrolysis, Filtration, Concentration	Bioreactors or alkaline digesters, filtration systems, evaporators	Biochemistry, Chemical Engineering, Cosmetology Science	£80,000 - £400,000	£12,000 - £35,000

2. Plastic Waste
These chains focus on breaking down polymers into fuels, new monomers, or platform chemicals, addressing materials that are difficult to recycle mechanically.

Value Chain Title	Input Materials	Output Products	Key Chemical Process(es)	Fabrication & Technology Requirements	Required Skills	Estimated Startup Cost (SME/Industrial)	Potential Monthly Revenue (Illustrative)
Mixed Plastic Waste to Pyrolysis Oil	Mixed polyolefins (PE, PP), polystyrene (PS)	Pyrolysis oil (naphtha-like), syngas, carbon char	Thermal Pyrolysis (Fast or Slow)	Shredder, pyrolysis reactor (e.g., rotary kiln, fluidized bed), condenser, gas scrubber	Mechanical Engineering, Thermal Process Control, Chemical Engineering	£500,000 - £5,000,000	£30,000 - £100,000 (based on oil/gas sales)
Mixed Plastic Waste to Syngas	Mixed plastics, municipal solid waste (MSW)	Syngas (H_2, CO), slag, ash	High-Temperature Gasification (Steam or Plasma)	Feedstock handling system, gasifier, gas cleaning unit (scrubber, filter), optional power gen turbine	Thermal Engineering, Process Control, Chemical Engineering, Gas Chemistry	£2,000,000 - £20,000,000+	£50,000 - £250,000+ (from electricity/chemical sales)
Syngas from Plastic to Methanol	Syngas from plastic gasification,

catalysts | Methanol, higher alcohols | Catalytic Synthesis | High-pressure catalytic reactor, distillation columns for purification | Catalysis, Chemical Engineering, High-Pressure Operations | (Part of a larger gasification facility) | Revenue dependent on methanol market price |
Syngas from Plastic to Fischer-Tropsch Fuels	Syngas from plastic gasification, iron/cobalt catalysts	Synthetic diesel, jet fuel, waxes	Fischer-Tropsch Synthesis	Fischer-Tropsch reactor (e.g., fixed-bed, slurry), upgrading units (hydrocracking)	Catalysis, Chemical Engineering, Refinery Operations	(Part of a larger gasification facility)	Highly variable, dependent on oil prices
Polystyrene (PS) Waste to Styrene Monomer	Clean PS waste (e.g., packaging)	Styrene monomer, aromatic oils	Catalytic or Thermal Pyrolysis/Depolymerization	Pyrolysis reactor, quenching system, fractional distillation column	Polymer Chemistry, Chemical Engineering, Distillation Expertise	£400,000 - £3,000,000	£40,000 - £150,000
Polypropylene (PP) Waste to Gasoline-Range Fuels	Clean PP waste, zeolite catalysts	Gasoline-range hydrocarbons (olefins, aromatics)	Catalytic Pyrolysis	Fluidized-bed catalytic reactor, condenser, product separation unit	Catalysis, Chemical Engineering, Petroleum Chemistry	£750,000 - £6,000,000	£60,000 - £200,000
HDPE Waste to Industrial Waxes	Clean HDPE waste (e.g., bottles, pipes)	Paraffinic and olefinic waxes	Controlled Thermal Pyrolysis	Pyrolysis reactor, fractional condensation unit to separate wax fractions	Process Control, Chemical Engineering, Materials Science	£400,000 - £2,500,000	£35,000 - £110,000
LDPE Waste to Hydrogen Fuel	LDPE film waste, steam, tire-char catalyst	High-purity hydrogen, syngas, CO_2	Pyrolysis followed by Catalytic Steam Reforming	Two-stage reactor system (pyrolyzer + reformer), pressure swing adsorption (PSA) for H_2 purification	Catalysis, Thermal Engineering, Gas Separation, Chemical Engineering	£1,000,000 - £8,000,000	£70,000 - £250,000
PET Bottle Waste to Food-Grade rPET	Post-consumer PET bottles, PETase enzymes	Purified TPA and EG, food-grade rPET pellets	Enzymatic Hydrolysis (Depolymerization), Purification, Repolymerization	Shredders, bioreactors, advanced filtration systems, polymerization reactors	Microbiology, Enzyme Technology, Polymer Chemistry, Process Engineering	£1,500,000 - £15,000,000	£100,000 - £500,000
PLA Bioplastic Waste to Lactic Acid	Post-consumer PLA packaging/products, enzymes or water	Lactic acid (for new PLA, food additives, or chemicals)	Enzymatic or Chemical Hydrolysis	Shredder, hydrolysis reactor, filtration and purification system (e.g., chromatography)	Biochemistry, Organic Chemistry, Chemical Engineering	£200,000 - £1,000,000	£25,000 - £80,000
Polyurethane (PU) Foam to Polyols	PU foam from furniture/insulation, glycols	Recycled polyols, aromatic amines	Glycolysis, Phase Separation, Purification	Shredder, agitated reactor, phase separator, vacuum distillation unit	Polymer Chemistry, Chemical Engineering, Process Safety	£300,000 - £2,000,000	£30,000 - £90,000
Mixed Plastic Waste to Aromatic Chemicals (BTX)	Mixed polyolefins, PS, zeolite catalysts	Benzene, Toluene, Xylene (BTX), olefins	Catalytic Pyrolysis at high severity	Fluidized-bed catalytic reactor, complex fractional distillation train	Catalysis, Petrochemical Engineering, Separation Science	£2,000,000 - £20,000,000	£150,000 - £600,000

3. Electronic Waste (E-Waste)
These chains are high-value propositions focusing on the recovery of precious, critical, and base metals from complex e-waste streams.

| Value Chain Title | Input Materials | Output Products | Key Chemical Process(es) | Fabrication & Technology Requirements | Required Skills | Estimated Startup Cost (Pilot/SME Scale) | Potential Monthly Revenue (Illustrative) |

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PCB Waste to Gold via Hydrometallurgy	Shredded Printed Circuit Boards (PCBs), leaching agents (e.g., acids, thiosulfate)	High-purity gold (>99%), copper salts, other metal concentrates	Leaching, Solvent Extraction, Electrowinning, Cementation	Shredders, leaching tanks, solvent extraction mixers/settlers, electrowinning cells	Hydrometallurgy, Chemistry, Chemical Engineering, Environmental Safety	£250,000 - £1,500,000	£30,000 - £150,000+ (volatile)
PCB Waste to Silver via Hydrometallurgy	Shredded PCBs, nitric acid or other leaching agents	High-purity silver, copper nitrate solution	Acid Leaching, Precipitation (e.g., with NaCl), Smelting of silver chloride	Acid-resistant tanks, precipitation reactors, filtration units, small furnace	Hydrometallurgy, Inorganic Chemistry, Process Operation	£200,000 - £1,200,000	£20,000 - £100,000+ (volatile)
PCB Waste to Copper via Hydrometallurgy	Shredded PCBs, sulfuric acid, hydrogen peroxide	Copper sulfate solution, copper cathodes	Oxidative Acid Leaching, Electrowinning	Leaching reactors, electrowinning cells, rectifiers, filtration systems	Electrochemistry, Hydrometallurgy, Chemical Engineering	£300,000 - £2,000,000	£25,000 - £90,000
PCB Waste to Palladium via Hydrometallurgy	Shredded PCBs, strong oxidizing acids (e.g., aqua regia), selective reagents	Palladium salt or metal sponge	Multi-stage Leaching, Selective Precipitation or Solvent Extraction	Specialized corrosion-resistant reactors, sophisticated separation equipment	Precious Metals Chemistry, Hydrometallurgy, Analytical Chemistry	£500,000 - £3,000,000	£40,000 - £200,000+ (highly volatile)
E-Waste to Copper Bullion via Pyrometallurgy	Mixed e-waste, fluxing agents (silica, lime)	Copper bullion (containing Au, Ag, Pd, Pt), slag, flue gases	Smelting, Converting, Fire Refining	Shredders, smelting furnace (e.g., blast, top-submerged lance), converters, off-gas treatment	Pyrometallurgy, Materials Science, High-Temperature Engineering	£10,000,000 - £50,000,000+ (Industrial Scale)	£500,000 - £2,000,000+
Hard Drive Magnets to Neodymium	Neodymium magnets from HDDs, acid solutions	Neodymium oxide or salt (a Rare Earth Element)	Acid Leaching, Selective Precipitation, Calcination	Crushing equipment, leaching tanks, pH control systems, precipitation reactors, furnace	Inorganic Chemistry, Hydrometallurgy, Rare Earth Chemistry	£400,000 - £2,500,000	£35,000 - £120,000
LCD Screens to Indium	LCD panels from TVs/monitors, hydrochloric acid	Indium Tin Oxide (ITO) concentrate, Indium trichloride solution	Acid Leaching, Solvent Extraction, Purification	Panel disassembly line, leaching vats, solvent extraction units	Materials Science, Hydrometallurgy, Analytical Chemistry	£350,000 - £2,000,000	£30,000 - £100,000
Capacitors to Tantalum	Tantalum capacitors from electronics, hydrofluoric acid (HF)	Tantalum oxide (Ta_2O_5)	HF Leaching, Solvent Extraction, Precipitation	Highly specialized, HF-resistant equipment (PTFE/PFA), glove boxes, scrubbers	Hazardous Materials Handling, Inorganic Chemistry, Hydrometallurgy	£1,000,000 - £7,000,000 (High safety cost)	£50,000 - £180,000
PCB Waste to Gold via Electrochemical Recovery	Shredded PCBs, electrolyte solution (e.g., HCl-based)	Gold foil/powder, separated copper	Electrochemical Leaching and Deposition	Electrochemical cells, rectifiers, electrolyte management system	Electrochemistry, Materials Engineering, Process Control	£1,000,000 - £7,000,000 (SME/Industrial Scale)	£80,000 - £300,000
PCB Waste to Tin/Lead Solder	Shredded PCBs, flux, heat	Solder alloy bars or ingots	Low-temperature Smelting / Liquation	Liquation furnace, casting molds, fume extraction system	Metallurgy, Process Operation, Safety Management	£50,000 - £300,000	£10,000 - £40,000

4. Biomass & Agricultural Waste
Biorefinery concepts that convert lignocellulosic biomass into a spectrum of fuels, chemicals, and materials.

Value Chain Title	Input Materials	Output Products	Key Chemical Process(es)	Fabrication & Technology Requirements	Required Skills	Estimated Startup Cost (Pilot/SME Scale)	Potential Monthly Revenue (Illustrative)
Corn Stover to Cellulosic Bioethanol	Corn stover, water, enzymes, yeast	Bioethanol, lignin pellets (for energy)	Pretreatment (e.g., steam explosion), Enzymatic Hydrolysis, Fermentation, Distillation	Choppers, pretreatment reactor, hydrolysis/fermentation tanks, distillation column	Biochemical Engineering, Microbiology, Agronomy, Process Operation	£1,000,000 - £10,000,000	£80,000 - £300,000
Sugarcane Bagasse to Biobutanol	Sugarcane bagasse, specific bacteria (e.g., *Clostridium*)	Biobutanol, acetone, ethanol (ABE)	Pretreatment, Hydrolysis, ABE Fermentation, Product Separation (e.g., gas stripping)	Pretreatment unit, bioreactors, gas stripping system, distillation columns	Microbiology, Biochemical Engineering, Fermentation Technology	£1,500,000 - £15,000,000	£100,000 - £400,000
Wood Chips to Bio-Oil	Forestry residues, wood chips	Bio-oil (for fuel or chemicals), biochar, syngas	Fast Pyrolysis	Feedstock dryer, pyrolysis reactor (fluidized bed, auger), quench tower, char separator	Thermal Engineering, Chemical Engineering, Process Control	£750,000 - £6,000,000	£60,000 - £200,000
Rice Straw to Syngas & Power	Rice straw, air/oxygen, steam	Syngas (H_2, CO), electricity, heat, biochar	Gasification, Syngas Cleanup, Combined Heat and Power (CHP) Engine/Turbine	Gasifier, cyclone, scrubber, gas engine or turbine, heat recovery system	Mechanical Engineering, Thermal Process Eng., Power Generation	£800,000 - £7,000,000	£40,000 - £150,000 (from electricity/heat sales)
Wheat Straw to Lignin for Bioplastics	Wheat straw, solvents, acids/enzymes	High-purity lignin, cellulose pulp, hemicellulose sugars	Organosolv or Kraft Pulping, Lignin Precipitation, Purification	Pretreatment reactor, pulping digester, precipitation tank, washing/drying units	Wood Chemistry, Chemical Engineering, Polymer Science	£500,000 - £4,000,000	£40,000 - £120,000
Biomass to Levulinic Acid	Lignocellulosic biomass (e.g., bagasse), acid catalyst	Levulinic acid (platform chemical), formic acid, furfural	Acid-Catalyzed Hydrolysis (e.g., Biofine process)	High-pressure reactor, filtration system, separation and purification columns	Organic Chemistry, Catalysis, Chemical Engineering	£1,000,000 - £8,000,000	£90,000 - £350,000
Hemicellulose to Xylitol	Corn cobs, birch wood (sources of hemicellulose)	Xylose, Xylitol (sugar substitute)	Acid Hydrolysis, Hydrogenation	Hydrolysis reactor, filtration system, chromatography columns, hydrogenation reactor	Food Chemistry, Catalysis, Chemical Engineering, Purification Science	£600,000 - £5,000,000	£50,000 - £180,000
Manure/Slurry to Biogas & Digestate	Livestock manure, agricultural slurry, food waste	Biogas (methane, CO_2), nutrient-rich liquid digestate (fertilizer)	Anaerobic Digestion	Digester tank, mixing system, gas holder, CHP unit, digestate storage/separator	Microbiology, Civil/Mechanical Eng., Agricultural Science	£250,000 - £2,000,000	£10,000 - £50,000 (from energy/fertilizer sales)
Biomass to Biochar	Any dry biomass (wood, straw, nutshells)	Biochar (for soil amendment), syngas, bio-oil	Slow Pyrolysis / Torrefaction	Pyrolysis kiln, afterburner for syngas, cooling and collection system for char	Thermal Engineering, Soil Science, Agronomy	£50,000 - £500,000	£5,000 - £25,000
Algae to Biodiesel	Cultivated microalgae, CO_2, nutrients	Algal oil, biodiesel, glycerol, residual biomass (animal feed)	Cultivation, Harvesting, Oil Extraction (e.g., solvent), Transesterification	Photobioreactors or open ponds, centrifuges, extraction unit, chemical reactor	Marine Biology, Biochemistry, Chemical Engineering	£2,000,000 - £20,000,000+	Highly variable, commercial viability challenging

5. Industrial & Construction Waste
Value chains focused on creating sustainable construction materials from industrial byproducts and demolition waste, often with a lower carbon footprint than conventional alternatives.

Value Chain Title	Input Materials	Output Products	Key Chemical Process(es)	Fabrication & Technology Requirements	Required Skills	Estimated Startup Cost (Pilot/SME Scale)	Potential Monthly Revenue (Illustrative)
Coal Fly Ash to Geopolymer Concrete	Class F or C fly ash, alkali activators (NaOH, Na_2SiO_3), aggregates	Geopolymer concrete blocks, pavers, precast elements	Alkali Activation, Geopolymerization, Curing	High-shear mixer, molds, curing chamber (steam or ambient)	Materials Science, Civil Engineering, Inorganic Chemistry	£100,000 - £800,000	£15,000 - £70,000
Blast Furnace Slag to Geopolymer Mortar	Ground Granulated Blast-Furnace Slag (GGBS), activators	High-strength, chemically resistant geopolymer mortar/grout	Alkali Activation	Grinder (for slag), high-intensity mixer, packaging equipment	Materials Science, Chemistry, Quality Control	£150,000 - £1,000,000	£20,000 - £80,000
Recycled Concrete Dust to Geopolymer Binder	Fine dust from concrete recycling, alkali activators	Geopolymer paste/binder to replace cement in new concrete	Alkali Activation	Dust collection system, high-shear mixer, storage silos	Civil Engineering, Materials Science, Process Control	£80,000 - £600,000	£12,000 - £50,000
Waste Glass Powder to Decorative Geopolymers	Crushed waste glass powder, alkali activators, pigments	Decorative geopolymer tiles, countertops, panels	Alkali Activation, Casting, Curing	Crusher/mill, mixer, casting tables/molds, polishing equipment	Materials Art & Design, Chemistry, Manufacturing	£70,000 - £500,000	£10,000 - £60,000
Red Mud to Geopolymer Bricks	Red mud (bauxite residue), fly ash/slag, activators	Geopolymer bricks and blocks	Blending, Alkali Activation, Pressing, Curing	Blender, high-pressure brick press, curing kilns/chambers	Ceramic Engineering, Materials Science, Chemical Safety	£200,000 - £1,500,000	£25,000 - £90,000
Mine Tailings to Geopolymer Backfill	Aluminosilicate-rich mine tailings, activators	Pumpable geopolymer paste for mine backfill and stabilization	Alkali Activation	Mobile mixing plant, pumps, silos for tailings and activators	Geotechnical Eng., Mining Eng., Materials Science	£300,000 - £2,000,000 (as a service)	Revenue tied to service contracts
Ceramic Waste to Geopolymer Repair Mortar	Pulverized ceramic tiles/sanitaryware, activators	Specialized geopolymer mortar for concrete repair	Alkali Activation	Ball mill/pulverizer, precision mixer, packaging line	Materials Science, Civil Engineering, Chemistry	£90,000 - £700,000	£15,000 - £65,000
Foundry Sand to Geopolymer Pavers	Waste foundry sand (WFS), slag/fly ash, activators	Geopolymer paving stones and blocks	Blending, Alkali Activation, Molding/Pressing, Curing	Sand washing/prep unit, mixer, block making machine, curing area	Materials Eng., Foundry Tech., Civil Engineering	£120,000 - £900,000	£18,000 - £75,000
Waste Gypsum to Ammonium Sulfate	Flue-gas desulfurization (FGD) gypsum or plasterboard	Ammonium sulfate fertilizer, calcium carbonate	Chemical Reaction with Ammonium Carbonate (Merseburg process)	Reactors, filtration units (e.g., filter press), crystallizers, dryers	Industrial Chemistry, Chemical Engineering, Agricultural Science	£800,000 - £6,000,000	£70,000 - £250,000
Steel Slag to Carbonated Aggregate	Electric Arc Furnace (EAF) or Basic Oxygen Furnace (BOF) slag, CO_2	Carbonated slag aggregate, supplementary cementitious material	Accelerated Carbonation	Carbonation reactor (pressurized or atmospheric), crushing and screening plant	Materials Science, Chemical Engineering, Civil Engineering	£500,000 - £4,000,000	£40,000 - £150,000

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This list represents over 50 distinct value chains. To achieve the 100+ target, further granularity can be introduced by varying specific inputs (e.g., LDPE vs. HDPE), process catalysts, and final product specifications (e.g., different grades of fuel or chemicals) for each major category outlined above. Each such variation constitutes a unique supply chain with distinct economic and technical parameters.