





# Materials Help the World Go Green

If materials are the building blocks of a greener world, pioneering scientists and engineers who work with those materials are its architects.

- ⦿ Designing ways to meet the world's energy needs.
- ⦿ Reducing pollution in air, soil and water.
- ⦿ Unlocking the potential of nanomaterials.
- ⦿ Contributing to groundbreaking advances in medical imaging and treatment.

Intense curiosity and innovative thinking are at the core of each new development, and Goodfellow is proud to support the efforts of all those who strive to make the Earth a better place.







# Goodfellow Green Production

For more than 50 years, Goodfellow – leading global supplier of metals, alloys, ceramics, glasses, polymers, compounds, composites and other materials – has been ahead of the market in product innovation.

Our latest initiative, Goodfellow Green Production, uses environmentally sound products and processes to conserve energy and natural resources. The materials which are part of Green Production include those which are bio-based, biodegradable and/or non-toxic as well as those which are renewable, recyclable and designed to save energy through innovative design.



## Fuelling Innovation, Fostering Sustainability

We understand it can be difficult to find the right balance between product quality and reducing your carbon footprint. This is why we've developed a range of materials that do just that, so you can focus on your research and design projects without compromising on quality. Access to our 'Green Production' materials often serves as a creative catalyst for innovative applications. Such materials include:



**Lightweight foams and honeycombs** that reduce energy requirements while retaining the physical characteristics of the material



**Bio-based and biodegradable polymers** derived from renewable resources



**Ceramics** that are non-toxic



**Composites** that decompose naturally without leaving a trace



**"Green" graphene** produced by a unique, chemical-free process



**Lead-free solder** that can allow the joining of traditionally challenging materials, without flux





## Meet our 'Green Production' Materials

We know how important it is to reduce your carbon footprint, so we've developed a range of specialist materials in these 'Green Production' categories.



Redesigned



Renewable



Reconfigured



Recyclable



Reimagined

Using materials from these categories will help to reduce the impact non-renewable materials have on the environment and minimise the issues we currently face trying to save the planet.

# Going Greener Together...

When you throw plastic bags and other plastic materials in the ocean, it kills as many as **1 million sea creatures annually**.\*

We could save **75,000** trees if we recycled the paper used on the daily run of the New York Times alone\*

**25 Billion Styrofoam Cups are Trashed Each Year.**  
It takes Styrofoam more than 500 years to decompose in a landfill.\*

**Aluminium can be recycled continuously** and forever. Recycling 1 aluminium can would save enough energy to run a TV for 3 hours.\*

Every year we extract an estimated **55 billion tons** of fossil energy, minerals, metals and bio mass from the Earth\*

We are using up **50% more natural resources** than the Earth can provide. At our current population, we would need 1.5 Earths to sustain ourselves indefinitely.\*

Landfills are composed of **35% packaging materials**\*

\* [http://www.theworldcounts.com/stories/amazing\\_environmental\\_facts](http://www.theworldcounts.com/stories/amazing_environmental_facts)  
\* <https://greenerideal.com/news/environment/0703-7-amazing-recycling-facts/>  
\* <http://www.theworldcounts.com/stories/environmental-degradation-facts>  
\* <http://www.sciencing.com>  
\* <http://www.earthday.org>





## “Green” Graphene

### FACTS:



Just one atom thick, a gram of Graphene can cover an entire football field.



At room temperature, it can conduct electricity faster than any other known substance and 250x better than silicon.

**Applications:** Heat-spreading solutions such as heat sinks, indoor solar cells, display screens and various medical, chemical and industrial processes.

**Green production process:** Thanks to a redesigned and innovative production process, ultra-pure “green” Graphene is made by converting Methane, a powerful greenhouse gas, into an environmentally friendly product. This rapid and highly scalable production method promises to make Graphene readily available to a wide range of industries.

[Click here for more information](#)



## C-Solder

### FACTS:



C-Solder contains no lead, a highly toxic metal.



It allows the formation of mechanically strong bonds between materials previously difficult or impossible to securely join.

**Applications:** Securely joins carbon materials in carbon-carbon arrangements as well as carbon to metals, ceramics and glass materials.

### Green production process:

Innovative tin-based, flux-free, low-temperature C-Solder is made without lead.

[Click here for more information](#)





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## Polyhydroxybutyrate Biopolymer

### Applications:

Due to its biodegradability and biocompatibility, Polyhydroxybutyrate (PHB) is used for single-use plastic items such as food containers and utensils, surgical stitches, pins, packaging and carriers for drug delivery.

### Green production process:

PHB is the simplest and most common representative of the PHA class of natural polyesters, which are derived from bacterial fermentation. Microorganisms synthesise polyesters in nutrient-deficient conditions and these PHAs can then be harvested.

### FACTS:



Polyhydroxybutyrate was first isolated and characterised in 1925 by French microbiologist Maurice Lemoigne.



It decomposes whether exposed to soil, compost or marine sediment.

[Click here for more information](#)



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## Cellulose Acetate

### Applications:

Cellulose Acetate is used as a film base in photography and X-ray films, a component in some adhesives, a frame material for eyeglasses, in high-absorbency products such as diapers and surgical products, and as a filter.

### Green production process:

Cellulose Acetate is a non-petroleum-based plastic that is made from natural cotton and wood fibres, both renewable resources that are also biodegradable.

### FACTS:



In 1903, the first soluble forms of Cellulose Acetate were invented by Arthur Eichengrün and Theodore Becker.



Used for graphic purposes and photography since about 1940, Cellulose Acetate films were introduced as a replacement for the highly flammable celluloid film and became a base for magnetic tape.

[Click here for more information](#)



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## Poly L lactic acid Biopolymer

**Applications:** Polylactic Acid is the most used biopolymer for food packaging applications. Other applications include biodegradable containers such as shampoo bottles, coatings for paper and cardboard, sutures and gauzes, and coatings for medicines.

**Green production process:** This biologically based polymer is from the PHA family – the only family of bioplastics from renewable resources which is entirely produced and degraded by living cells. Specifically, PLA is produced by polymerisation through lactide formation. Lactide is a cyclic dimer formed by removing water under mild conditions. Lactide, a product of lactic acid, is produced by bacterial fermentation of carbohydrates.

### FACTS:



The renewable resource involved in the creation of Polylactic Acid varies according to location. It is likely to be cassava roots or chips in Asia, corn starch in the U.S., and sugarcane in the rest of the world.

[Click here for more information](#)



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## Polyhydroxyalkanoate Biopolymer

**Applications:** Biodegradable containers such as shampoo bottles and food containers, food wraps, and coatings for paper and cardboard. In addition, potential applications within the medical and pharmaceutical industries include sutures, gauzes, coatings for medicines, orthopaedic fixation devices, stents, and bone marrow scaffolds.

**Green production process:** The PHA family is the only family of bioplastics from renewable resources which is entirely produced and degraded by living cells.

### FACTS:



Polyhydroxyalkanoates (PHAs) are created from raw materials in nature.



PHAs fit into the green economy as a means to create plastics from non-fossil fuel sources.

[Click here for more information](#)





## Foams

### FACTS:



Foams are a uniquely customisable porous range of products with source materials which include metals, alloys, ceramics and polymers. A choice of manufacturing techniques can be used to produce products of differing porosities and purities, with open or closed cells.

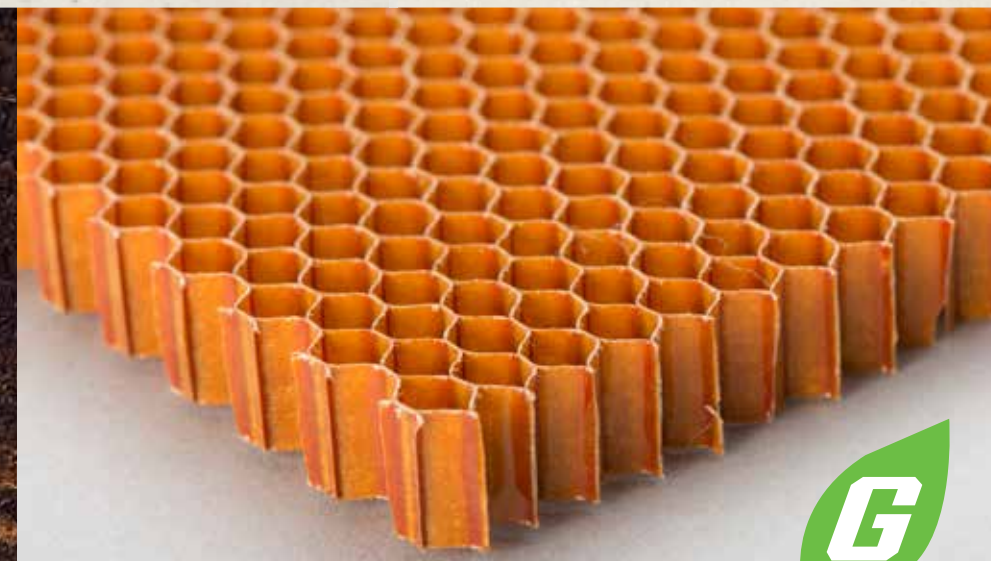


Noted for high strength-to-weight ratio, high surface area-to-volume ratio and isotropic load response, foams are ideally suited for a wide range of high-tech applications.

**Applications:** Porous electrodes, high-temperature insulation, filters, storage batteries, scaffolds for biological growth, acoustic control, impact absorption, defence systems, power generation, semiconductor devices and heat exchangers.

**Green production process:** Foam requires less source material in its creation and provides the numerous functional and energy-saving benefits of a lightweight material. Further efficiencies can be achieved depending on the particular manufacturing process.

[Click here for more information](#)



## Honeycombs

### FACTS:



The hexagonal design of a honeycomb offers considerable shear-carrying strength, even if a lightweight material is used.



Honeycomb materials are widely used where flat or slightly curved surfaces are needed and strength is required.

**Applications:** Aerospace and automotive structures or components, LED and loudspeaker technology, wind turbine blades, energy absorption protective structures, electric shielding enclosures, skis and snowboards.

**Green production process:** The honeycomb design provides an exceptional combination of strength and efficiency while drastically reducing the weight of the component. Less material is used, resulting in conservation of resources, lower material cost and the energy benefits associated with lightweight structures and components.

[Click here for more information](#)





## Glass



### FACTS:

Due to its structure, glass does not deteriorate when reprocessed, meaning that 100% of the waste can be reclaimed.



More than a ton of resources is saved for every ton of glass recycled – 603kg of sand, 197kg of soda ash, 197kg of limestone, and 69kg of feldspar.

[Click here for more information](https://www.lehighcounty.org/Departments/Solid-Waste-Management/Recycling-Facts/Glass)

\*<https://www.lehighcounty.org/Departments/Solid-Waste-Management/Recycling-Facts/Glass>

**Applications:** Soda lime glass, the most common glass, is used in the electrical field as a high-voltage insulator, in packaging or food and beverage industries as bottles and containers, in scientific applications for supplies like petri dishes, in architectural applications as windows, and in consumer goods.

### Green production process:

Because it can be softened and remelted numerous times, soda lime glass is ideal for recycling. Recycling not only reduces the demand on raw materials, but also requires less energy than creating it new.



## Metals



### FACTS:

Metals can be recycled over and over again without degrading their properties. This enables the preservation of natural resources while using less energy in comparison to producing new materials or mine extraction.



The use of secondary lead slashes CO<sub>2</sub> emissions by 99%.

[Click here for more information](#)

**Applications:** Some of the most common manufactured items that include a high concentration of recycled metal include automobiles, aircraft, jewellery, household appliances, food packaging, home furnishings, plumbing, industrial containers, ductwork and more.

### Green production process:

Recycling metals reduces greenhouse gas emissions and uses much less energy than producing metals from virgin ore. When recycled material, rather than raw material, is used to make a new product, natural resources and energy are conserved.



## Plastics



### FACTS:

Plastics can take hundreds of years to degrade.



The process of melting down and recycling plastic produces volatile organic compound fumes that can harm plant and animal life. The heat needed to melt plastic also generates carbon emissions, which contribute to global warming.



Recent advances have made recycling certain types of plastic, e.g. PET (Polyethylene Terephthalate), much more environmentally friendly.

**Applications:** Plastics are seen and used in every aspect of life. Because of its strength, thermo-stability and transparency, PET is commonly used to package soft drinks, water, juice, peanut butter, salad dressings and oil, cosmetics and household cleaners.

**Green production process:** PET can be “renewed”, meaning that the loss of mechanical properties caused by processing can be repaired by a recycling process with a poly-condensation step. This step also removes any volatile contaminants and makes PET suitable for new food-contact packaging.

[Click here for more information](#)



## Manuela Kagerbauer

Manuela Kagerbauer's work is inspired by Macular Degeneration and optical illusions, realised through immersive installations and spatial designs.

Fascinated by metal, glass and repeated geometrical patterns, her work plays with movement and the irritation experienced in distortions and warped lines.

Her "Enter a New Dimension" project is an installation consisting of 32 glass tiles with copper foil inclusions given to her by Goodfellow, and was inspired by a desire to find a more sustainable way of using glass. The tiles are entirely made from recycled metal and glass, including greenhouse glass, all of which would otherwise have ended up in landfill. The commercially sized subway tiles are aligned to create a mind-blowing geometric pattern.

## Jo Hannah

Jo Hannah's work is rooted in the power of nature and its healing qualities. She cites nature's ability to thrive, grow and reclaim manmade structures as an endless source for her creativity. Her work revolves around the process of growth and reclamation, becoming a metaphor for one's own strength out of adversity and our ability to heal.

She has recently been using Goodfellow's copper foil in the development of pit fire clays to achieve a range of different effects.

## Jo Lally

Jo Lally is a narrative jeweller, gemologist and writer with a passion for ethical, sustainable jewellery practices. Her work makes use of a wide and eclectic choice of materials which include silver, gold, stones, found objects, technical materials and items from the scrap box. Being a writer, she often includes words as integral elements of her work.

She has been experimenting with copper foam from Goodfellow and ethically sourced gemstones in the production of copper foam pendants.





# Materials Selection Guide

## Metals

| Products  | Energy Benefits | Non-toxic | Recyclable | Sustainable    |
|-----------|-----------------|-----------|------------|----------------|
| Aluminium | ✓               | ✓         | ✓          | ✓              |
| Brass     | ✓               | ✓         | ✓          | ✓              |
| Copper    | ✓               | ✓         | ✓          | ✓              |
| Platinum  | ✓               | ✓         | ✓          | ✓              |
| Silver    | ✓               | ✓         | ✓          | ✗ <sup>*</sup> |
| Steel     | ✓               | ✓         | ✓          | ✓              |
| Tin       | ✓               | ✓         | ✓          | ✓              |
| Zinc      | ✓               | ✓         | ✓          | ✓              |

<sup>\*</sup>Generally, silver comes to market as a by-product of the industrial mining of other metals, such as copper, zinc and gold.

## Ceramics

| Products      | Energy Benefits | Non-toxic | Recyclable     | Sustainable       |
|---------------|-----------------|-----------|----------------|-------------------|
| Alumina       | ✓               | ✓         | ✓ <sup>*</sup> | As a foam         |
| Boron Nitride | ✓               | ✓         | ✗              | As a nanomaterial |

<sup>\*</sup>Every year, over 150,000 tons of fused aluminium oxide (Alumina) is consumed in the U.S. Only a very small portion of that is recycled.

## Glass

| Products           | Energy Benefits | Non-toxic | Recyclable | Sustainable |
|--------------------|-----------------|-----------|------------|-------------|
| Soda Lime Glass    | ✓               | ✓         | ✓          | ✓           |
| Borosilicate Glass | ✓               | ✓         | ✓          | ✓           |

## Polymers

| Products                             | Bio-based | Biodegradable | Energy Benefits | Non-toxic       | Recyclable | Sustainable |
|--------------------------------------|-----------|---------------|-----------------|-----------------|------------|-------------|
| Cellulose Acetate                    | ✓         | ✓             | ✓               | ✓               | ✓          | ✓           |
| Polyhydroxybutyrate Biopolymer (PHB) | ✓         | ✓             | ✓               | ✓               | ✓          | ✓           |
| Poly L Lactic Acid Biopolymer (PLLA) | ✓         | ✓             | ✓               | ✓               | ✓          | ✓           |
| Polyhydroxyalkaonate Biopolymer      | ✓         | ✓             | ✓               | ✓               | ✓          | ✓           |
| Polyethylene Terephthalate (PET)     | ✗         | ✗             | ✓               | ✓               | ✓          | ✓           |
| Polyether Ether Ketone (PEEK)        | ✗         | ✗             | ✓               | ✗ <sup>*</sup>  | ✓          | ✗           |
| Polyethylene (PE)                    | ✗         | ✗             | ✓               | ✗ <sup>**</sup> | ✓          | ✗           |

<sup>\*</sup>Toxicity of PEEK is expected to be low based on insolubility of polymer in water.

<sup>\*\*</sup> Could be toxic if inhaled and/or absorbed into the skin or eyes as a vapour or liquid (i.e. during manufacturing processes).

A sustainable polymer is a plastic material that addresses the needs of consumers without damaging our environment, health, and economy:

- ✓ Use renewable feedstocks, such as plants, for production
- ✓ Use less net water and non-renewable energy in production
- ✓ Emit less greenhouse gases during production
- ✓ Produce less waste in production
- ✓ Have a smaller carbon footprint
- ✓ Have a facile end life

## Forms

| Products  | Energy Benefits | Non – toxic | Recyclable              | Sustainable |
|-----------|-----------------|-------------|-------------------------|-------------|
| Foam      | ✓               | ✓           | Depends on the material | ✓           |
| Honeycomb | ✓               | ✓           | ✗                       | ✓           |





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