

The Ingeo™ Journey



ingenious materials from plants not oil

The Ingeo Journey

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The Ingeo™ Journey

Ingeo™ is a unique bio-based material made from plants instead of oil. It was introduced globally in 2003 on a commercially viable scale by NatureWorks LLC, a company dedicated to more sustainable and environmental product and business development. NatureWorks' mission is to drive real environmental progress through its global market development and communication of the many and varied **Ingeo™** branded products made today from either **Ingeo™** natural plastic or fiber.

Since the journey began, **Ingeo™** products have progressed from idea to reality, spearheading a broad assortment of creative innovations from **Ingeo™** natural plastics for food & beverage packaging, to serviceware, consumer electronics, and durable goods, as well as **Ingeo™** fiber for clothing, homeware and personal care products.

It is a responsible and contemporary innovation material that gives consumers alternative choices for products with a natural origin and a compelling environmental message.

Ingeo™ performs well in both its plastic and fiber forms. Used appropriately, its functional qualities deliver performance without compromise to match a growing demand for eco-sensible products that help create the possibility of a better environmental footprint for all involved.

Ingeo™ offers a significant reduction in green house gas emissions which contribute towards global warming and climate change, cuts our dependence on oil as a resource material, and offers the potential for significant waste reduction.

Ingeo™ is fast becoming the ubiquitous better lifestyle choice for more responsible contemporary consumers.

And, as with any new technologies or materials, there is often a real need to clarify some of the facts about how it's made and what makes it different from the oil based plastics and fibers it is replacing today.

- Raw Material Facts
- Production Facts
- Product Facts
- Product Recovery Facts



Raw Material Facts

1.

Not made from oil

- 100% annually renewably resourced.
- **Ingeo™** currently uses plant sugars from field corn as the source material for manufacture.
- This innovation is a journey, where corn is only the starting point, not the destination – **Ingeo™** can be made from any abundantly available sugar.

2.

Today, these plant sugars are derived from field corn that is already grown for many industrial and functional end-uses.

In context, **Ingeo™** uses less than 1/20th of 1% (0.05%) of the annual global corn crop today, and as such contributes little to no impact on international or local food chains.

Ingeo™ doesn't require corn, it only needs a sugar source, whatever is most readily available depending on the geography. In the future, **Ingeo™** will be made from cellulosic raw materials, agricultural wastes and non-food plants.

3.

The manufacture of **Ingeo™** does not require genetically modified (GM) materials. The **Ingeo™** biopolymer is made from plant based sugars as its source and is certified by Genescan to contain no genetic material of any kind. However, current US corn grown produces a mixed stream of GM and conventional corn. To address variable market demands around the world relating to this issue, NatureWorks offers three certified sourcing options. →

Sugars taken from plants that can be grown every year are transformed into the revolutionary **Ingeo™** biopolymer needed to create a whole new family of **Ingeo™** innovations for fresh food packaging solutions, food serviceware, bottles, films, laminated and foamed structures, clothing, personal care, the home, garden, and consumer electronics.

There is a debate about bio industries contributing to a crisis in food prices. What about Bioplastics? What are the real facts?

Access to affordable food is a fundamental human right and new thinking and innovative strategies are needed to help the world sustain itself. There is no single reason and no single solution to the crisis:

- Volatility in energy prices drives volatility in everything else, from fertilizer and farm equipment, to transportation and food processing.
- Combination of population and wealth growth equals a higher meat demand and feedstock price hikes.
- Extreme weather and poor harvests mean an upward pressure on prices. Supply and demand balance is very easily disrupted.

According to the November 2008 International Energy Association report:

- Oil prices will rebound to more than \$100 a barrel as soon as the economy recovers and will exceed \$200 by 2030.
- "While market imbalances temporarily cause prices to fall back, it is becoming increasingly apparent that the era of cheap oil is over. Current global trends in energy supply and consumption are unsustainable."
- Output from the world's oil fields is declining at a rate of 9%.

www.worldenergyoutlook.org

Alternative sugar sources



Sugar beet



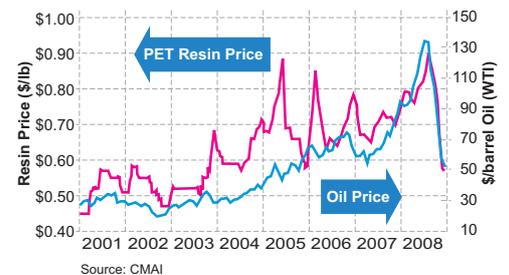
Sugar cane



Corn



Wheat



Three ways to buy Ingeo™.

1st option

Genescan Certified

NatureWorks has made sure that their unique Ingeo™ resin and the dextrose feed stock material used exclusively in its manufacture does not contain any GMO material at all due to the high heat used in the basic manufacturing process.

Ingeo™ is certified to be free of any genetic material by GeneScan Inc., recognized by both government and NGOs as the leading authority for testing food, feed and raw materials.

2nd option

Feedstock Sourcing

NatureWorks gives real choices and takes the extra steps needed for those customers who want other options by purchasing a crop weight equivalent to customers needs and mixing this in a stream of conventional and GM corn grown in the area. While it is not possible to sort the streams, for customers who so choose, NatureWorks replaces the purchase of GM corn with corn which is source certified and guaranteed non-modified.

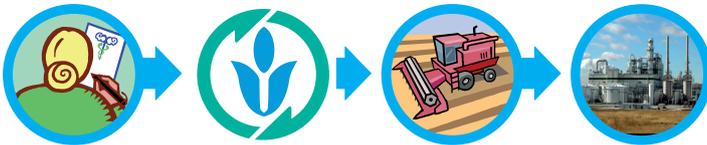
3rd option

Identity Preserved

NatureWorks offers a choice that shows their commitment to innovation, an Ingeo™ biopolymer production batch made from identity preserved conventional corn sources to satisfy our retail customer's particular needs in this sensitive area. The customer commitment to production is contingent on following longer lead times and guaranteed volumes to accommodate appropriate farm to production commitment on a single batch.

Ingeo™ anticipates and counters the continuing instability in the price of crude oil and the subsequent volatility in the price of traditional polymers which are derived from oil as a raw material.

How Source Offsets Work



“We believe that a transition to annually renewable, plant based feedstocks to meet more of society’s needs can actually relieve some of the underlying root causes on commodity pricing.”

Marc Verbruggen, CEO of NatureWorks LLC

Development of Future Cellulosic Feedstocks

Next steps in the Journey

NatureWorks’ commitment to responsible innovation means there is a long term plan to transition the current raw material supply to one which uses a new carbohydrate feedstock. This will be a change to residual biomass as the new raw material for Ingeo™ production. This is a key part of the Ingeo™ journey to responsible innovation by offering more tailored sourcing options, while expanding and supporting the growth of the biopolymer Industry by making it possible to manufacture from multiple sites around the world.



Production Facts

NatureWorks patented technology was the first to industrialize the conversion of sugars to bioplastics. The commercial scale of the process meant that a range of **Ingeo™** biopolymer lifestyle products has fast become a real and better alternative to fossil fuel resourced products around the world today.

In 2009, NatureWorks LLC established a nameplate annual production capacity of 140,000 tons of **Ingeo™** biopolymer.

Evolution: Further improvements in an already strong Eco-Profile.

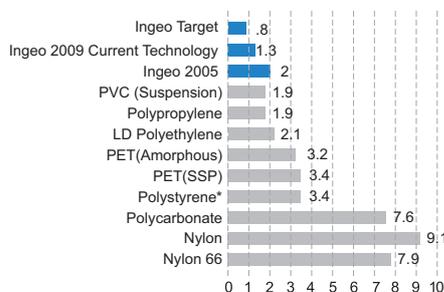
From an environmental perspective, the green house gas emissions and the non renewable energy usage associated with **Ingeo™** manufacture are two key indicators of primary interest. With its launch, **Ingeo™** immediately offers the market a significant improvement versus incumbent plastics in each of these eco-credentials.

In parallel with market introduction of its first generation **Ingeo™** production technology, NatureWorks continues fundamental R&D in order to bring further eco-profile improvement to the market. Peer reviewed research¹ confirms that NatureWorks 2nd generation production technology, which has been on-stream since late 2008, provides **Ingeo™** with the strongest credentials of any commercially available plastic. Compared to amorphous PET for example, **Ingeo™** now generates 59% less GHG emissions, and uses 47% less non-renewable energy.

¹ Vink E.T.H. et al. The eco-profiles for current and near-future **Ingeo™** polylactide production. Industrial Biotechnology, Volume 3, Number 1, 2007, Page 58-81.

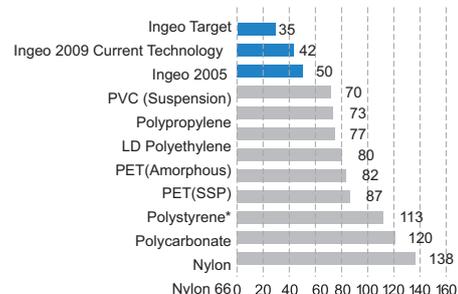
During commercialization and scale-up of this 2nd generation production technology (2006-2008), NatureWorks offset the emissions relating to electricity usage in its own facility and it's supply chain in order to more immediately provide to end markets these long term improvements in eco-credentials.

In 2009, the improved **Ingeo™** eco-credentials now come 'hardwired' in the polymer itself, without the use of green power certification. Of course, this remains an option for interested customers.



GREENHOUSE GAS EMISSIONS FROM CRADLE TO POLYMER FACTORY GATE (KG CO₂ EQ. / KG POLYMER)

* (HIPS/GPPS AVG)



NON RENEWABLE ENERGY USE FROM CRADLE TO POLYMER FACTORY GATE (MJ / KG POLYMER)

* (HIPS/GPPS AVG)

Next steps in the Journey

The original **Ingeo™** biopolymer provided the benchmark for a better carbon footprint and now 2nd generation **Ingeo™** manufacturing is redefining an improved environmental footprint, without the need for renewable energy certificates. Longer term, new options are expected, relating to further process optimization, additional plant locations, and cellulose feedstocks.



Product Facts

Ingeo™ biopolymer is currently used to design more than 20 different types of lifestyle products. The many unique benefits that come with **Ingeo™** hinge on NatureWorks' technology leadership in making responsible materials for products that look good, perform well and have a compelling environmental message built in at the heart of their production.

Each product category leverages relevant **Ingeo™** attributes and benefits².

Packaging

Containers • Bottles • Films • Food Serviceware • Coatings • Foam

• Fit for Purpose

Ingeo™ properties allow for a wide variety of performance food & beverage packaging and foodservice setting innovations.

• Appearance

Ingeo™ has excellent gloss, transparency and clarity for containers and bottles.

• Food preservation

Ingeo™ provides exceptional flavor and aroma barrier properties, allowing things to taste like the day they were made.

• Versatility

Ingeo™ is easy to shape, mold, emboss and print.

• Innovations for rigid packaging

Ingeo™ has good form and stiffness properties and in combination with lower density makes for lighter packages compared to PET.

• Innovations for Flexible Packaging

Ingeo™ films have better folding and twist fold capabilities, superb printability, and easier shrink properties than conventional films. On top of this, **Ingeo™** works with ease in structured, layered performance films.

• Foam Alternatives

Ingeo™ foam packaging provides the long sought-after alternative to polystyrene foam. Safe for use with meat products, dairy and whole eggs. Lightweight & tough **Ingeo™** foam packaging offers great moisture barrier properties.

• Paper Coating Alternatives

Ingeo™ functions well in hot and cold drink applications, with good moisture, grease and oil resistance.

• Environment

Using **Ingeo™** brings a series of measurable environmental benefits to products and users choosing plant based natural plastics instead of oil sourced materials.³

• Safety

Ingeo™ natural plastic does not contain and has never contained any Bisphenol A ("BPA"). **Ingeo™** packaging grades are food -grade compliant.

• Disposal options⁴

Ingeo™ offers more end-of-life options: mechanical and chemical recycling, clean incineration and industrial composting.



Food Waste Diversion from Landfill.

Unfortunately today, most compostable food waste around the world is literally 'contaminated' with petroleum based plastics – the presence of which condemn food waste to landfill, rather than more environmentally beneficial composting. A truly compostable solution like **Ingeo™** offers enormous potential, enabling the composting of the entire waste stream from food service operations.

² See separate technical papers on individual performances available on www.natureworkslc.com

³ See **Ingeo™** Life Cycle Analysis available on www.natureworkslc.com

⁴ See complete End-of-life documents for full details on www.natureworkslc.com

Packaging

Containers • Bottles • Films • Food Serveware • Coatings • Foam

Ingeo™ and Recycled PET

PET bottles are recycled to some extent today, and “r-PET” is seeing some use as a raw material for single use packaging. Many believe that packaging made from “r-PET” must have a strong environmental footprint. What are the facts here? And how do packages from Ingeo™ & r-PET really compare?

The Institute for Energy and Environmental Research (IEFU), Heidelberg, Germany, www.ifeu.de, conducted a head-to-head lifecycle comparison on more than 40 different combinations of clamshell packaging made from Ingeo™ natural plastic, PET, and rPET⁵. The lifecycle study took a broad range of end-of-life scenarios into account.

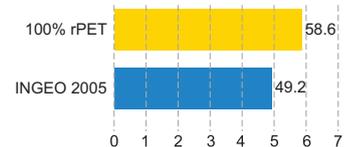
Both Ingeo™ and rPET clamshells outperformed PET packaging in terms of lower overall greenhouse gas emissions and lower overall energy consumed. Ingeo™ clamshells clearly offered further advantages over the petroleum-based rPET in numerous comparisons.



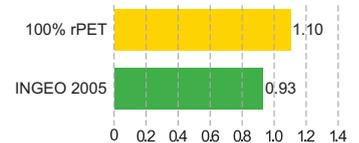
“Brand owners and converters will lower the carbon and energy footprint of clamshell packaging by moving away from PET and rPET to Ingeo™ polymer. This is true with today’s virgin Ingeo™ and, in the longer term, recycled Ingeo™ will decrease that footprint even more. Furthermore, the high performance of Ingeo™ biopolymer in clamshell applications means that less material may be required to manufacture them – on average 25 percent less.”

Marc Verbruggen, president and CEO of NatureWorks, the manufacturer of Ingeo™.

⁵ “Life Cycle Assessment of food packaging made of Ingeo™ biopolymer and (r)PET”: Addendum to the LCA study on food packaging made of Ingeo™ biopolymer and alternative materials [2006]. Final report, October 2008, eu - Institut für Energie- und Umweltforschung Heidelberg GmbH (IEFU)



RESULTS FOR CLIMATE CHANGE
KG CO₂ EQ. / 1000 CLAMSHELLS



RESULTS FOR NON RENEWABLE PRIMARY ENERGY
G JOULES / 1000 CLAMSHELLS

Durable Plastics

Consumer Electronics • Casings Cards • Media

- **Performance**

Ingeo™ is an exceptionally durable and fit-for-purpose contemporary low impact material.

- **Versatility**

Ingeo™ is easy to blend, laminate and combine with other polymeric performance materials and can be injection molded, shaped, embossed and printed on most conventional existing systems.

- **Appearance**

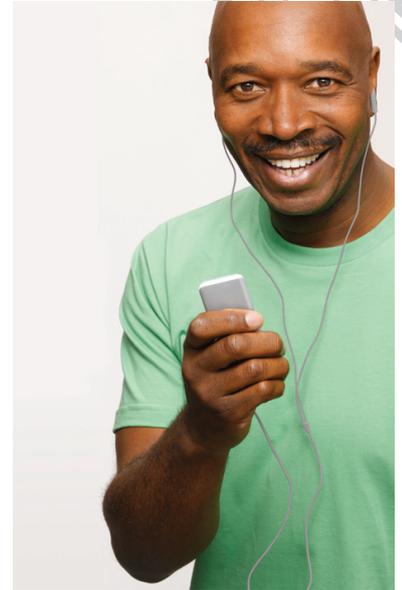
Ingeo™ has excellent gloss as well as transparency and clarity when needed.

- **Environment**

Using **Ingeo™** brings a series of measurable environmental benefits to products and users choosing plant based natural plastics instead of oil sourced polymer.

- **Design Possibilities**

Ingeo™ offers designers the ability to “design with the end in mind.” A creative process that considers the full life cycle of products, from inspiration to disposal – the concept of true ‘zero waste.’



Cradle-to-Cradle Design

Whereas “recycling” deals primarily with handling waste as delivered when goods have become garbage, zero waste by contrast, looks holistically at the redesign of industrial, commercial and consumer goods to avoid generating ‘waste’ in the first place.

Ingeo™ gives designers the freedom to fundamentally rethink the raw materials they use - designing with end-use and end-of-first-life in mind. A new responsibility for the entire lifecycle of a product and its packaging will change the face of solid waste management, managing resources to eliminate waste and pressure on landfill.

Fibers

Nonwovens • Apparel • Homeware

- **Versatility**

Ingeo™ fiber is versatile, available in both filament and staple spun forms. It can make a wide variety of textile styles from dress to sportswear, furnishings to drapes and soft nonwoven baby wipes to tough landscape textiles.

- **Performance**

Ingeo™ can outperform traditional synthetics for UV light resistance, hypoallergenic properties, outstanding moisture management, stain resistance, low odor retention, easy care/quick dry, breathability, comfort and insulation properties.

- **Security of supply**

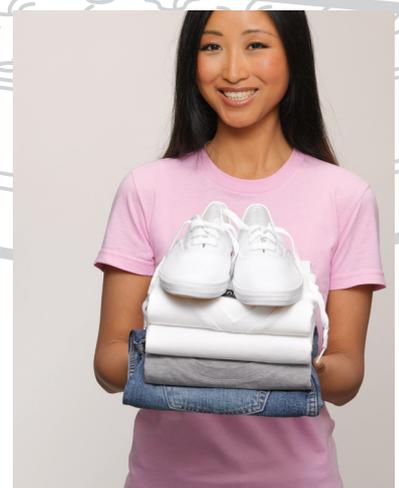
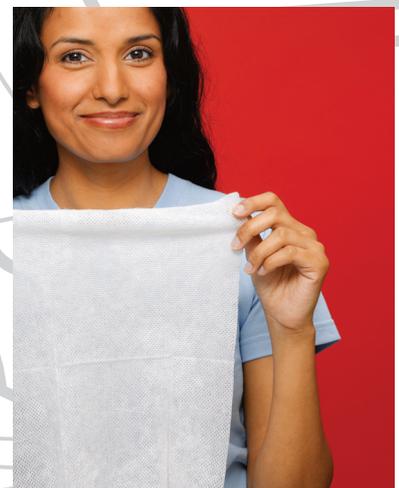
Ingeo™ fiber is made entirely from annual renewables, making it less subject to market volatility and inevitable scarcity.

- **Environment**

Using **Ingeo™** brings a series of measurable environmental benefits to products and users choosing plant based fibers instead of oil sourced materials.

- **Innovation**

Ingeo™ has a unique environmental and creative message built in that when combined with the a broad range of design possibilities is motivating manufacturers to exploit and match the growing market demand for responsible design development in eco-sensible fashion, home and lifestyle products today.



Next steps in the Journey

With a dedicated policy for responsible innovation, NatureWorks is refining, improving and developing the next generation of high performance **Ingeo™** biopolymers in anticipation of both business and consumer needs. New generation **Ingeo™** resins & fibers will perform better through specialized and tailored polymer design to improve performance in manufacture and use.

Product Recovery Facts

When thinking about the issue of environmental impact, it's important to recognize that true environmental advantage starts at the beginning. By design, **Ingeo™** produces 60% less of the global warming emissions of the oil-based plastic PET that it replaces, even if both end up in a landfill. **Ingeo™** is better by every measure than the alternative traditional oil-based plastics.

That said... Ingeo™ also has more end-of-life options than any other plastic material:

- **Ingeo™** enables upcycling and recycling through either mechanical or chemical recovery processes. This is in stark contrast to most traditional plastics recovery schemes, which typically 'downcycle' their materials into lower value products which will ultimately end in landfill. **Ingeo™** can be uniquely recreated as a virgin raw material resource.
- **Ingeo™** offers options to the local infrastructure and systems in the locations where it is used with choices from clean incineration to industrial composting – a much needed solution when disposable packaging is heavily contaminated with food waste from foodservice operations.

In fact, Ingeo™ offers a unique menu of opportunities to help achieve a zero-waste environment.



Plastics Recycling – What's the situation today?

There are numerous incumbent fossil fuel based plastics in use today [e.g., plastics such as PET, polyethylene, PVC, polypropylene, and polystyrene], which are already at a scale where they could be recycled.

In spite of this, today only two of these plastics are actually being recovered and recycled at the post consumer level. Furthermore, although numerous consumer products and packaging are made from these two plastics, this actual recycle is occurring only for bottles:

- PET, typically used to bottle soda, water, and juice.
- High density polyethylene (HDPE), typically used to bottle milk, laundry detergent, etc.

For each of these plastic categories, bottle recycled rates are only ~ 25%.

[*2006 United States National Postconsumer Plastics Bottle Recycling Report*, Association of Postconsumer Plastic Recyclers, American Chemical Council, www.americanchemistry.com]

Why aren't more of these 2 plastics being recycled? And more broadly, why aren't all those other plastics being recycled?

The unfortunate reality is that the underlying economics of recycling are often not attractive. For those involved in making the plastic, it's often cheaper to simply make virgin, new plastics from new starting materials – oil or gas.

This is where the recycle potential for **Ingeo™** is exciting. Unlike conventional oil based plastics, **Ingeo™** can be simply and economically, recycled:

- an **Ingeo™** bottle can be remade into another bottle again and again,
- by contrast, oil-based incumbent plastic bottles are typically "down-cycled" into products of diminishing value such as decking, and are ultimately destined for landfill.
- **Ingeo™** provides the opportunity for economically viable, true closed-loop, cradle-to-cradle solutions.



Working together towards the goal of zero waste

- NatureWorks strongly supports recycling, composting and the concept of Zero Waste wherever possible.
- Current waste reduction systems are evolving and continued success relies on partnerships and momentum where comprehensive recovery or composting systems will successfully emerge once the critical mass of material is available to process.
- NatureWorks supports initiatives to achieve best results through local infrastructure, collection, processing to reach these targets while anticipating inevitable legislation designed to reduce waste.

Identifying Ingeo™ in the Recycle Stream

Near-infrared sorting is the industry's preferred plastics sorting technology because it can accurately identify the multiple different polymers already in use today (different polymers reflect an identifiable light spectrum – a unique 'fingerprint').

Tests on present-day sorting technology used widely by recyclers prove that **Ingeo™** can be identified in the mixed waste plastic with very high accuracy.

“NIR (near-infrared) systems can effectively remove Ingeo™ bioplastic and carton board from a mixed packaging stream.”

Waste Resources Action Program (WRAP), report published, June 2008, “Domestic Mixed Plastics Packaging Waste Option”. (WRAP is an internationally recognized not-for-profit company that helps individuals, businesses, and local authorities reduce waste).

There is a debate and concern about the impact bioplastics will have on the current plastics recycling infrastructure. Are bioplastics a contaminant to those plastics which are recycled today? What are the real facts?

NatureWorks LLC is committed to responsibly introducing its **Ingeo™** biopolymer into the market and the company has evaluated the ability of numerous sorting technologies.

- **Titech** (www.titech.com) has demonstrated the ability of its near-infrared sorting systems to eject concentrated amounts of PLA in a PET sorting operation. Sorting efficiency in a single pass was found to be a minimum of 97.5% accurate. Titech's near-infrared sorting is perhaps the most dominant technology used worldwide.

- **Unisensor** (<http://unisensor.luveno-net.de>) has shown its laser flake technology is fully capable of sorting PLA flakes from desired PET recycle streams at efficiencies as high as 96-99%. This is consistent with other plastics considered contaminants in the PET flake sorting technology.

- **MSS** (www.magsep.com) tested **Ingeo™** in its Aladdin near-infrared system. The test confirmed that **Ingeo™** emits a unique polymeric “signature.” The test demonstrated that **Ingeo™** comes up as “other plastics” in a system specifically designed to identify PET, PE, and other plastics. Its unique signature means that the equipment could be programmed to identify **Ingeo™** as **Ingeo™** or simply as “other plastics.”



Addressing the concerns of all Recyclers

Of course, not all recyclers today have the latest technology in sorting equipment installed – some still rely on manual identification systems. Because NatureWorks LLC is committed to responsibly introducing its **Ingeo™** biopolymer into any market and region which it supplies, the company works to address these concerns on an individual basis.

- Performing regional pilot studies in order to address the specific concerns of local recyclers.
- Utilizing alternative, low-cost technologies such as working with its customers to ensure that **Ingeo™** can also be uniquely identified by its behavior using something as simple as a blacklight.
- Working with State legislation such as the California Department of Conservation to team up with the local infrastructure & stakeholders and demonstrate system feasibility.

Ingeo™ in a landfill

Ingeo™ does not break down or biodegrade in a conventional landfill. Neither does anything else. The reality is that today's waste reduction systems capture just a small amount of the total plastic flowing into landfills, and options for recycling and composting that material are limited. Due to these limitations, some products will end up in a landfill. And because a landfill does not offer the climate necessary to compost, it is unlikely that any product will decompose efficiently. That said, if both bio-based **Ingeo™** product and oil-based product end up in a landfill, the **Ingeo™** products are already better, offering the reductions in GHG emissions and nonrenewable energy usage, something oil-based products cannot achieve.

Ingeo™ and safety

In contrast to polycarbonate, NatureWorks LLC does not use and has never used any amount of Bisphenol A ("BPA") during the manufacture of **Ingeo™** biopolymer.

At present, a number of different resins, each with very different properties and composition, fall within the catch-all category of "7-OTHER" (this includes **Ingeo™** and polycarbonate). This SPI code should never be used to determine whether an article is safe or unsafe as the code was not designed as a means to determine the exact and particular type of plastic used to manufacture the article bearing that code.

Feedstock Recovery

The recycling of post consumer waste to the original Ingeo™ feedstock, lactic acid, will now become a commercial reality, with a world scale Belgian lactic acid producer. Galactic announced it's intent as the first company to invest in the back to feedstock, 'chemical' recycling of Ingeo™. With its LOOPLA® recycling process, Galactic is building a 1000 ton plant lactic acid plant based on PLA feedstocks which neatly closes another part of the Ingeo™ circle of production. Galactic is collaborating with NatureWorks to collect both post industrial and post consumer Ingeo™ intermediates and finished products to feed their process.



Progress in Recycling

A new Government and Industry Alliance for a 21st Century Sustainable Packaging Recycling Program is the first tangible demonstration of both NatureWorks vision, the government's commitment to the concept of zero waste and the maximization of resources. This new two year program, with the Department of Conservation in California has been set up to make California a leader in 21st century sustainable packaging, by developing the capacity for recycling programs to separate new environmental bioplastics from other recyclables using optical sorting technology which will;

- Address both the sustainability of new packaging materials in terms of natural resources used and carbon mitigation achieved.
- Evaluate the systems for recycling and re-use of these materials.
- Maximize the opportunity posed by materials such as Ingeo™, which in the long term will be highly recyclable with a low environmental footprint.

- Preserve the integrity of current PET systems from the growing potential of contamination.
- Design a multi-plastic sorting business model that will benefit the environment while at the same time be profitable and affordable to most or all communities.

“With polymeric fibres in the environment, the volume in waste disposal and landfill is very high. They do not degrade very readily and landfills are decreasing in number. Better recovery and disposal solutions are absolutely essential for a more balanced global waste management strategy. Plant based biopolymers will be part of such a solution.”

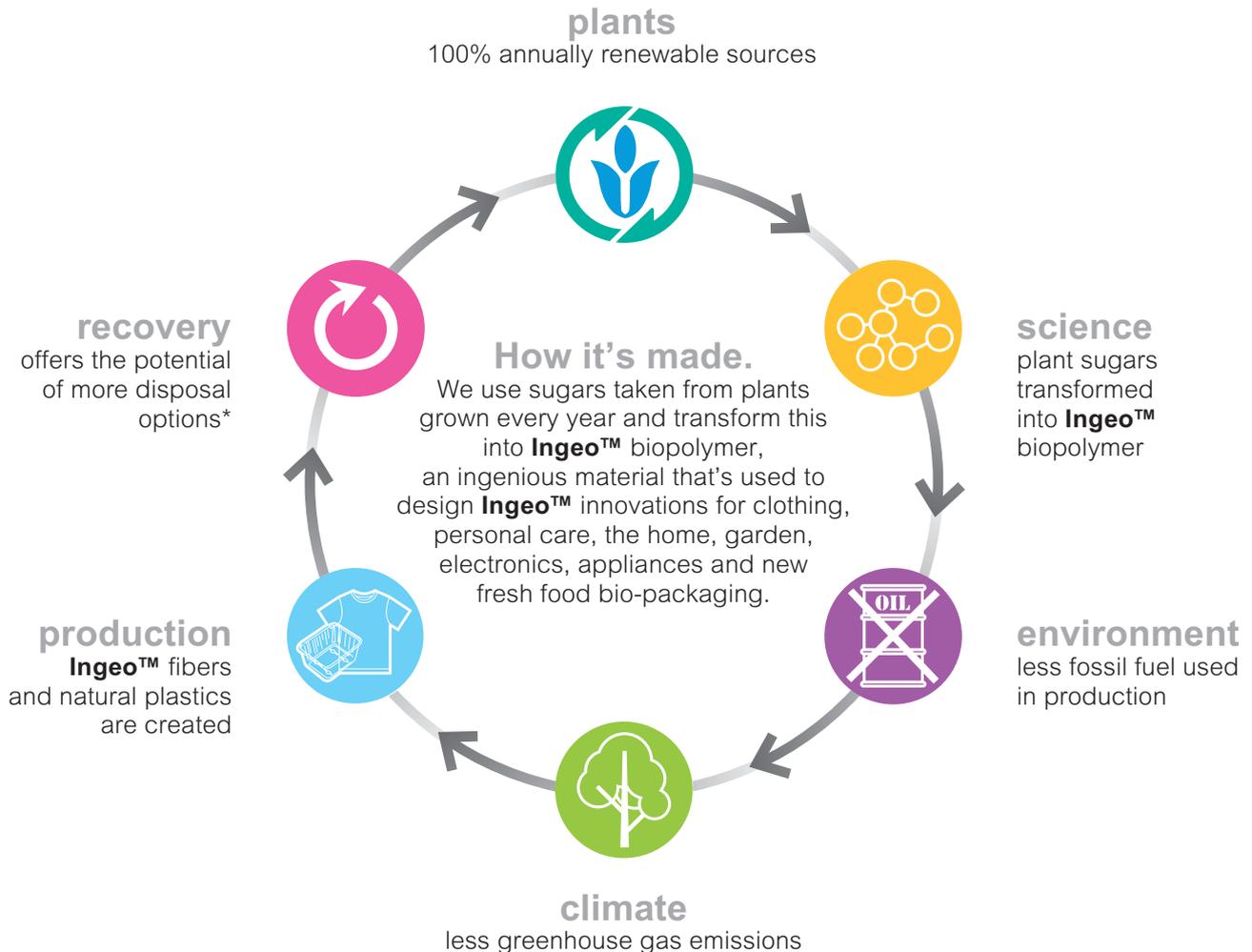
Dr. Richard Blackburn, Head of Green Chemistry Group, Centre for Technical Textiles UNIVERSITY OF LEEDS, and lead steering group for RITE, Reducing the Impact of Textiles on the Environment.

Next steps in the Journey

In concert with ASTM International and interested plastics producers and stakeholders, NatureWorks is working to establish a unique material identification code (formerly the SPI code) for Ingeo™. In the future, an improved means of material identification will better support optimum and appropriate plastics recovery treatment whether that be composting, mechanical recycling, feedstock recovery or incineration.



Society is placing a greater importance on moving away from an unsustainable dependence on oil. Ingeo™ is a vehicle to help meet that need.



NatureWorks LLC, and Ingeo™ : making businesses work better for everyone to make better choices. Better for the planet, so better for consumers and ultimately better for business too.

