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ELInsights Green Plastics

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EL Insights: Green Plastics

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EL Insights: Green Plastics

Green Plastics at a Glance

Green plastics, or bioplastics, refers to plastic materials and products that are either:

- Biodegradable
- made wholly or partly from biological materials, or
- both.

The market was until recently dominated by biodegradable materials, but bio-based, non-biodegradable plastics have grown in a big way, and now make up about 58 percent of global production capacity.

These materials appeal to customers because they can reduce greenhouse gas emissions, avoid depleting fossil resources, and reduce landfill volumes. They can be used for a wide variety of purposes, including both disposable and durable goods, and ongoing innovation promises great growth for the industry.

Materials and Technologies

Bio-Based

Some of the most common bio-based polymers are:

Polyethylene Terephthalat (PET): Partly bio-based PET, known as bio-PET, is a non-biodegradable plastic which uses bioethanol from sugar cane. It is the leading drop-in bioplastic – a biopolymer that can be directly substituted for its petrochemical counterpart. Globally, the development of drop-ins has been one of the largest drivers for innovations in the market. [1]

On average bio-PET comprises 30 to 35 percent biomass. Coca-Cola jumpstarted the bio-PET market by introducing its PlantBottle, made of up to 30 percent bioplastic, in 2009.[2]

To facilitate this, the company started an elaborate multi-national bio monomer supply chain, and licensed partners to accelerate the development of 100 percent bio-based PET.[3] Coca-Cola's efforts were the major contributor towards 30 percent bio-PET's growth into the single largest bioplastic,[4] with production capacity of 452,000 metric tons in 2011.[5]

[1] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

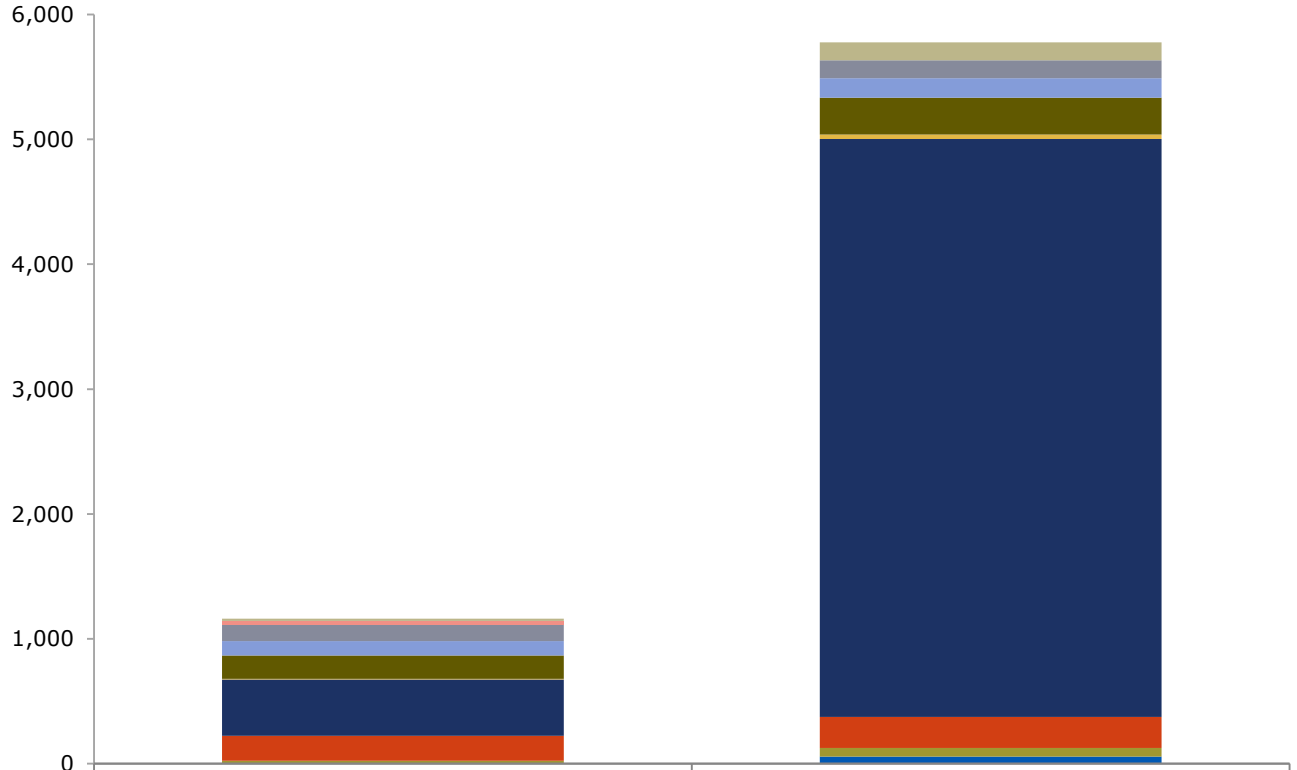
[2] http://www.environmentalleader.com/2009/11/16/after-dasani-test-coke-begins-global-rollout-of-plantbottle/

[3] http://plasticsengineeringblog.com/2012/08/13/the-race-to-100-bio-pet/

[4] Email correspondence, Michael Carus, Nova-Institute, May 1, 2013.

[5] European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012. http://en.european-bioplastics.org/press/press-pictures/labelling-logos-charts/

Bioplastics Production Capacity by Type,
2011 and 2016, Thousand metric tons



		2011	2016
Biodegradable	PHA	19	144
	Regenerated cellulose	28	-
	Biodegradable starch blends	131	144
	Biodegradable polyesters	116	156
	PLA	187	295
	Other biodegradable	6	35
Biobased/ non-biodegradable	Bio-PET 30	452	4,629
	Bio-PE	200	248
	Bio-PA	19	69
	Other biobased/non-biodegradable	5	58

Source: Environmental Leader calculations, April 2013, based on European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012

Pepsi, meanwhile, introduced its own 100 percent bio-PET bottle in 2011.[6] Other common uses of bio-PET include trays and films. [7]

More on these companies' efforts can be found in the *Adoption by Businesses* section.

Polyethylene (PE) and polypropylene (PP): The bio-based versions of these plastics are 100 percent biomass, non-biodegradable polyolefins, based on bioethanol.[8,9,10] They are currently the most popular drop-in bioplastics after bio-PET.[11] Common uses include rigid containers, film wrap, barrier coatings and lidding.[12]

Polylactic acid (PLA): 100 percent biomass, biodegradable plastic.[13,14] Can be processed using most conventional polymer processing methods. PLA is strong but brittle.[15] Common uses include rigid containers, film and barrier coating.[16] This polymer is newer to the market but has great potential.[17]

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[6] http://www.environmentalleader.com/2011/03/15/pepsico-unveils-100-bio-based-rival-to-cokes-plantbottle/

[7] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[8] Ibid.

[9] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[10] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

[11] Ibid.

[12] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[13] http://wiki.chemprime.chemeddl.org/index.php/BIODEGRADABLE_PLASTICS

[14] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

[15] http://www.ncbi.nlm.nih.gov/pubmed/16398516

Polyhydroxy Alkanoates (PHAs): 100 percent biomass, biodegradable plastic.[18] Common uses include films, barrier coatings and trays.[19] Like PLA, PHA is fairly new but has good growth potential.[20]

Cellulose Acetate (CA): As a biopolymer, this plastic averages 50 percent biomass content. CA has good heat resistance and elasticity, and can replace some conventional plastics. It is comparable to polystyrene (PS), acrylonitrile-butadiene-styrene (ABS) and technical polypropylene (PP).[21]

Polyamide (PA): Also known as nylons, polyamides are the largest family of engineering plastics, with a wide variety of uses. They are often formed into microfilaments and yarns.[22] They are still mostly fossil-based, but the bio-based share of this plastic is trending upwards, and bio polyamides should reach about 60 percent by 2020.[23] PA is non-biodegradable.

[16] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[17] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[18] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

[19] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[20] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[21] http://www.umsicht.fraunhofer.de/en/business-units/renewable-resources/projects/biobased-softeners.html

[22] http://plastics.ides.com/generics/22/polyamide-nylon

[23] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

Polybutylene Adipate Terephthalate (PBAT): Like PLA, this thermoplastic can be processed using most conventional methods. It is flexible and tough.[24] This biodegradable plastic[25] is still mostly fossil-based, but the bio-based share is trending upwards, and bio-PBAT should reach about 50 percent by 2020.[26]

Polybutylene Succinate (PBS): A biodegradable plastic, though currently still mostly fossil-based.[27] The bio-based share of this plastic is trending upwards, and bio-PBS should reach about 80 percent by 2020.[28]

Polyvinyl Chloride (PVC): These compounds can be extruded, injection molded, compression molded, calendered, and blow molded to form a wide variety of products, both rigid and flexible.[29] Bio-based versions average 43 percent biomass.[30]

Polyurethane (PUR): This large family of polymers has widely ranging properties and uses, including coatings, elastomers and foams. They may be rigid or flexible, and have excellent abrasion resistance. The biobased versions are on average 30 percent biomass.[31]

[24] http://www.ncbi.nlm.nih.gov/pubmed/16398516

[25] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

[26] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[27] http://www.myriant.com/applications/pbs.cfm

[28] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[29] http://plastics.ides.com/generics/46/polyvinyl-chloride-pvc

[30] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[31] Ibid.

Starch blends: These are on average 40 percent biomass,[32] and biodegradable.[33] Common applications include loose fill, bags, films, trays and wrap film.[34]

One way to classify bio-based plastics is by how they are produced. Bioplastics can be produced directly by an organism; the organism can produce monomers or other precursors, that are then polymerized; the bio-based monomer may be combined with other monomers, which can be bio-based or not; or the bioplastics may be produced using biofillers, which include animal and plant-based materials.[35]

Biodegradable

As noted above, many bio-based plastics are also biodegradable. But not all biodegradable plastics are bio-based. There is a comparatively small group of petroleum-based, biodegradable plastics – and partly bio-based versions of these materials will likely be made in the near future.[36]

An important caveat: any product's claim to biodegradability is meaningless if it does not specify the conditions and timeframe under which the product will degrade. This is why standards have become such an

[32] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[33] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

[34] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[35] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[36] European Bioplastics, Fact Sheet: What are Bioplastics? http://en.european-bioplastics.org/wp-content/uploads/2011/04/fs/Bioplastics_eng.pdf

important force in the biodegradable plastic market. Where possible, European Bioplastics recommends that companies focus on the more specific claim of compostability.[37]

Some of the petroleum-based, biodegradable plastics are:

Polyglycolic acid (PGA): This is used in medicine and specialized applications.

Polycaprolactone (PCL): Used for mulch, seeding containers, and other agricultural purposes; and in medicine.

Polyhydroxybutyrate (PHB): Used for bottles, bags, films; disposable diapers; and medicine.

Polyhydroxyvalerate (PHBV): Used for films and paper coatings, with possible markets including biomedical applications and veterinary science.

Polyvinyl alcohol (PHV): Used in packaging designed to dissolve in water to release products such as laundry detergent, pesticides, and hospital washables.

Polyvinyl acetate (PVAc): Used for adhesives, boxboard manufacture, paper bags and paper lamination.[38]

[37] Ibid.

[38] http://wiki.chemprime.chemeddl.org/index.php/BIODEGRADABLE_PLASTICS

Markets and Applications

Bioplastics applications generally fall into two categories: disposable and durable goods.

Disposable goods: These include shopping bags, bottles, food packaging, trash bags, foam packaging, medical containers and blisterpacks.[39] Here, biodegradability tends to be more important than it is with durable goods. In some cases, a plastic product's biodegradability not only prevents that product taking up landfill space, but also allows contents to biodegrade – such as with compostable trash bags. In 2011, the biggest applications for bioplastics were shopping bags followed by bottles, though that should switch by 2016 as production capacity for bioplastic bottles grows by leaps and bounds.

Durable goods: Bio-based plastics can provide substitutes for many common products, such as furniture, fencing, pet toys, carpet, vehicle seats and trim, air conditioning hoses and ducts, and even apparel.[40] Technical applications, including automotive uses, were the third-largest destination for bioplastics in 2011 and should see strong growth to 2016.

[39] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[40] Ibid.

Vendors and Products

The following companies make compostable resins certified to either ASTM D6400 or ASTM D6868 standards *(see Standards section for more information).* Except where noted, the list is drawn from the Biodegradable Products Institute.[41]

Anqing Hexing Chemical Co. Ltd.: Makes uncolored resins sold as Hexing HX-ZBEI01, for blown film, injection molding, thermoforming and extrusion.

BASF: The company's Ecoflex and Ecovio plastics are fully biodegradable and compostable. Ecoflex is fossil-based, while Ecovio – a blend of ecoflex and PLA – contains renewable materials.[42]

Because We Care Pty, Ltd.: Makes BWC BF-90 resins for films.[43] Also produces a number of consumer products, including doggy bags, produce bags and garden products.[44]

Biome Bioplastics Ltd.: Its products include BiomeEP bioplastic polymers for flexible films, BiomeHT high-temperature bioplastics, BiomeCord starch-based biodegradable material for fibers, yarn and cords, BiomeClear biodegradable film, BiomeEasyFlow bioplastic for extrusion coating and lamination, and Biome Bioplast GF106/2 potato starch-based film.[45]

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41 http://www.bpiworld.org/BPI-Public/Approved/3.html

42 http://www.bioplastics.basf.com/faq.html

43 http://www.bpiworld.org/BPI-Public/Approved/3.html

44 http://www.becausewecare.com.au/

45 http://biomebioplastics.co.uk/products.php

Cardia Bioplastics: Makes Cardia Biohybrid and Compostable resins as well as compostable bags.[46]

Cereplast: Makes Cereplast Compostables brand starch-based polymer,[47] and Cereplast Sustainables bio-based resins, including Cereplast Bio-polyolefins grades.

Danimer Scientific: Makes ReNew Resins for papercoating of compostable products.

ECOTECH (China) Co., Ltd.: Makes compostable resins and Ecowil brand film, bag, and packaging products.

FKuR Kunststoff GmbH: Makes Bio-Flex brand PLA resins for blown films, cast films, injection molding extrusion and thermoforming.

Gio-Soltech, Ltd.: Makes Sol-Pol resin for film, sheet and injection molded products.

Grabio Greentech Corporation: Makes Grabio Greentech Resin GB 100 for the manufacture of blown films and bags.[48]

Green Chemical Co.: Makes GC8400 uncolored resins for extruded films.

Guangdong Shangjiu Biodegradable Plastics Co.: Manufactures BOR-Q-805F resins for making films, bags, and disposable packaging.

Guangzhou Bio-plus Materials Technology: Makes Bio-plus uncolored resins for extruded films.

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[46] http://www.cardiabioplastics.com/products

[47] NNFCC Renewable Polymers Factsheet: Bioplastics

[48] http://www.bpiworld.org/BPI-Public/Approved/3.html

Heritage Plastics: Makes BioTuf resins for manufacture of compostable bags and films.

Ingredion (formerly Corn Products International): Manufacturer and distributor of Evella, a fully compostable resin for production of films, bags and injection molded products.

Kingfa Science & Tech. Co., Ltd.: Manufactures ECOPOND Flex-262 and ECOPOND Flex-64D for making bags and films.

Kureha Corporation: Makes Kuredux resins for films and bags.

Meredian, Inc: Makes Meredian PHA Resins for films and bags.

Metabolix: Makes PHA biopolymers using corn, switchgrass, oilseeds and sugarcane.[49] Makes the Mirel family of bioplastics, including injection molding materials P1003, P5001, F1005, P1004/F1006, and M.vera B5002 film.

Mitsubishi Chemical Corporation: Makes PLA resins for extruded sheets.

Multibax: Produces Multibax MBIO-1 brand PCL-based resins for films and bags; also sells bags under the MBIO-2 tradename.

Nantong Huasheng Plastic Products: Makes uncolored films and bags from Nantong Huasheng PCOz resins. Sells shopping bags, can liners and other products.

NatureWorks: Makes the Ingeo family of PLA resins.[50] The company has over 15 resin grades for both

[49] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[50] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

plastics and fibers markets.[51] It is also involved in alternative feedstocks, with plans to use non-food feedstock at a plant in Thailand.[52]

Novamont NA: Makes Mater-Bi brand starch-based polymer. [53]

S-EnPol Co.: This subsidiary of Samsung Fine Chemicals makes biodegradable polymers for diverse applications, under the trade name of EnPol.

Shanghai Disoxidation Enterprise Development Co.: Makes BSR-09 resin, and films from BSR-09.

Suzhou Hanfeng New Material Co.: Makes single-use food service containers and packaging.[54]

Teknor Apex Company: Makes Terraloy Bioplastic Resins for blown film, cast film, injection molded goods, blow molded articles, thermoformed products, extruded sheets and profiles. On the high-performance end, Teknor Apex has a higher heat-resistant PLA for injection molding and extrusion/thermoforming.[55]

Tianan Biologic Material Company (TNN): Makes PHBV-based resins under the Enmat 100 brand name, for use in injection molding and film applications.

Tianjin Greenbio Material Co.: Makes resins under the Sogreen brand name.

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[51] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[52] Ibid.

[53] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[54] http://www.biohanfeng.com/en/ch/index.asp

[55] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

Zhejiang Hangzhou Xinfu Pharmaceutical Co.: Makes uncolored resins sold as Biocosafe 1903l, Biocosafe 1903F, and Biocosafe 1903E.

Zhejiang Hisun Biomaterials Co.: Makes white translucent resin, sold as Revode by Hisun, for manufacturing thermoformed, injection molded products.

Other major bioplastics players include (except where noted, this information comes from the Bioplastics Council[56] and NNFCC[57]):

Arkema: Developing high-performance bio-based plastics to replace petroleum-based engineering plastics.

Bioamber: This joint venture of US-based DNP Green Technology and France-based ARD operates a bio-based succinic acid plant in Canada, together with Mitsui & Co. Bioamber has plans to open a similar plant in Thailand in 2015, in cooperation with Mitsubishi Chemical and PTT Public Co.

BIOP Biopolymer: Makes BIOPAR brand starch-based polymer.

Biotec: Makes Bioplast brand starch-based polymer.

Braskem: The manufacturer is the leading player in bio-PE. Braskem also announced plans for a commercial-scale facility to produce bio-PP, starting this year.[58]

Cerestech: Makes Cereloy brand starch-based polymer.

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[56] Ibid.

[57] NNFCC Renewable Polymers Factsheet: Bioplastics. http://www.nnfcc.co.uk/publications/nnfcc-renewable-polymers-factsheet-bioplastics/at_download/file

[58] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

Clarifoil: Makes Clarifoil brand cellulosics.

Dow Chemical: Makes a bio-based PE.

DuPont: Makes renewably sourced materials such as Sorona, Hytrel RS and Zytel RS, Biomax starch-based polymer for PLA and Danisco plasticizer.

Ecospan: A materials research, development, and manufacturing company focused on bio-based plastics.

Genomatica: Plans to produce bio-based BDO (1,4-butanediol), which is used in the production of polyurethane, copolyester, polytetrahydrofuran (THF) fiber and rubber.

Innovia Films: Makes NatureFlex brand cellulosics.

Jamplast: The company distributes biopolymers, engineering polymers and commodity grade thermoplastics.

Limagrain Cereales: Makes Biolice brand starch-based polymer.

Novomer: Developed polypropylene carbonate (PPC) resin by combining propylene oxide with CO (carbon monoxide

Nypro: Makes plastics as well as bioplastic components for markets including healthcare, consumer & electronics, and packaging.

PHB Industrial Brasil: Makes Biocycle brand PHA.

Plantic Technologies: Makes Plantic brand starch-based polymer.

Polyden Folienfabrik: Makes Mulchfolie brand starch-based polymer.

PolyOne: Offers compound and thermoplastics polyurethane and is developing high-performance bio-based materials to replace petroleum-based engineering plastics.

Purac: Makes a lactide monomer PLA. Purac also has announced it will make stereocomplex PLA for higher temperature performance.

Rodenburg Biopolymers: Makes Solanyl brand starch-based polymer.

RTP: Developing high-performance bio-based plastics to replace petroleum-based engineering plastics.

Sidaplax: Makes EarthFirst brand PLA.

Starch Tech: Makes Re-NEW brand starch-based polymer.

Wenstus Kunstoff: Makes Wenterra brand starch-based polymer.

Benefits and Challenges

Benefits

Environmental: The main environmental benefits of bio-based plastics are reduced depletion of fossil resources and reduced greenhouse gas emissions. On both these measures, bio-based PLA has notably lower impact than petroleum-based polymers (including PP, HDPE, LDPE, PET, PS and PC), and bio-based PHA generally has lower impact still.

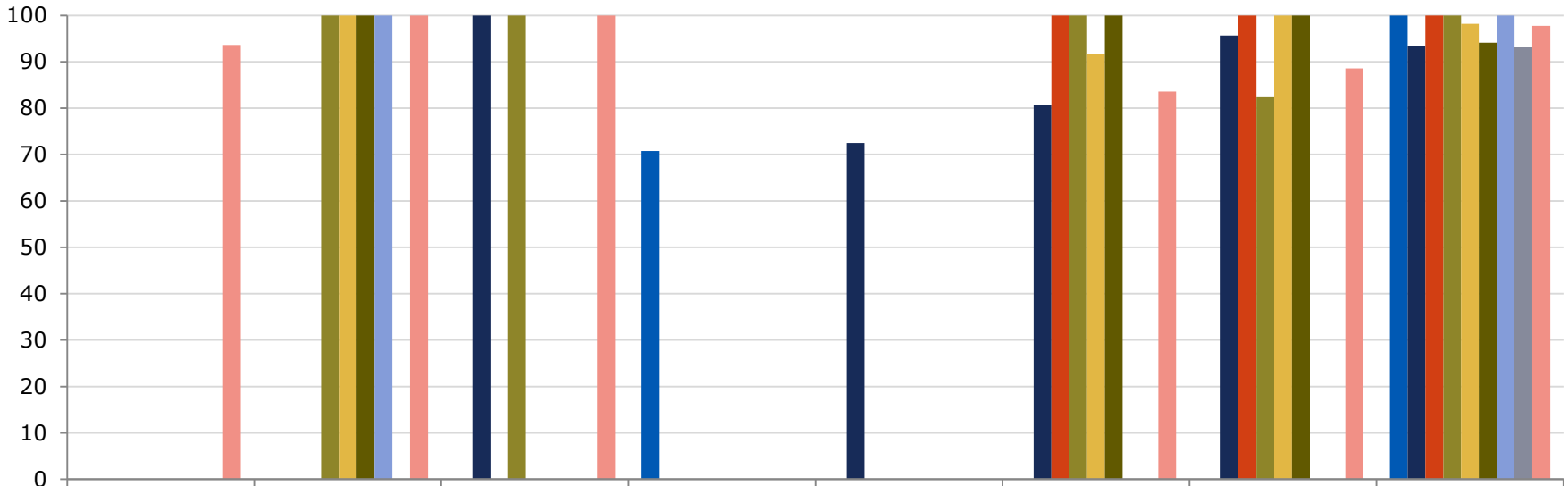
The benefits of bio-based polymers vary according to what plastic they are replacing. They save more fossil resources versus PC and PS, though savings versus PET, LDPE, HDPE and PP are still substantial.[59]

Meanwhile, Coca-Cola's initial studies indicate a bottle composed of 30 percent bioPET reduces carbon emissions by 20 percent, compared to a conventional PET bottle.[60]

[59] Roland Essel, Nova-Institute, Meta-Analysis of Life Cycle Assessments for Bio-Based Polymers (PLA & PHA). 5th International Congress on Bio-based Plastics and Composites, Cologne, March 15, 2012.

[60] http://www.environmentalleader.com/2010/06/17/coke-crs-report-carbon-footprint-down-nearly-12/

Discard rates for selected plastic resins and applications, 2010 (%)



	Durable goods	Plates and cups - all resins *	Trash bags	PET bottles and jars **	Bottles - white translucent homopolymers	Other plastic container	Bags, sacks and film	Other plastic packaging
PET				71				100
HDPE			100		73	81	96	93
PVC						100	100	100
LDPE / LLDPE		100	100			100	82	100
PP		100				92	100	98
PS		100				100	100	94
PLA		100						100
Other ***								93
ALL resins	94	100	100			84	89	98

* Due to source data aggregation, PET cups are included in "Other Plastic Packaging".
** Injection stretch blow molded PET containers.
*** Other resins include commingled/undefined plastic packaging recovery.
Some detail of discard rates by resin omitted due to lack of data.

Source: Franklin Associates, A Division of ERG, via EPA

The main environmental benefits of biodegradable plastics are reduced waste-to-landfill, where there are systems in place to capture and compost the plastic; and the production of useful end-products through composting. Composting also has the potential to save municipalities and companies money on landfill costs. Compost humus can be sold for $26-$100 per ton. Note that if biodegradable items are sent to landfill, they will not decompose, as landfills are actually designed to prevent decomposition.[61]

Risk reduction: Conventional plastics can create a risk of supply disruption, because of events such as oil embargoes.[62]

Time savings: The use of biodegradable plastic can save time in certain industries. For example, many crops are covered in a thin polypropylene mulch that has to be collected and recycled every season. A bioplastic mulch can dissolve and even improve the carbon content of the soil. Likewise, using compostable utensils can save restaurants time in sorting waste.[63]

"Coca-Cola's initial studies indicate a bottle composed of 30 percent bioPET reduces carbon emissions 20 percent, compared to conventional PET."

[61] http://www.bpiworld.org/Default.aspx?pageId=190439

[62] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[63] Ibid.

Customer appeal: Use of bio-based and biodegradable products can appeal to customers looking to lower their impact on the environment. Research shows, however, that there is considerable confusion about these terms. In a Genencor survey, 75 percent of Americans and 78 percent of Canadians said clothing made with bio-based enzymes was definitely or likely "green." Yet just 40 percent of Americans and 35 percent of Canadians actually recalled hearing the term "bio-based" before.[64]

Challenges

Costs: Bio-based plastics generally cost several times as much as their conventional equivalents, though this premium is set to diminish as bioplastics supply increases.[65]

Poor recyclability: European Bioplastics says bio-based versions of PE, PET and PVC are physically identical to their conventional counterparts, and can be recycled in the usual way. More problematic, it says, are new plastics like PLA and PHA that don't have an established recycling stream to tap into.[66] But according to the Bioplastics Council, many municipal recycling systems in the US do not accept the recycling streams (such as PET, HDPE, PVC, LDPE, PP and PS) that would process bioplastics.[67] The New York City Department of Sanitation meanwhile says that few if any recycling programs accept bioplastics, and that recycling bioplastics requires specific equipment that is not yet commonly available.[68]

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[64] Genencor Household Sustainability Index, Summary Report, April 2011. http://www.genencor.com/fileadmin/user_upload/genencor/documents/Genencor_HSI_SummaryReport.pdf

[65] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[66] European Bioplastics Fact Sheet: Closed loop systems and resource efficiency with bioplastics, May 2011.

[67] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[68] http://www.nyc.gov/html/nycwasteless/html/resources/plastics_bio.shtml

Lack of composting facilities: Nearly all compostable bioplastics require industrial composting facilities – they can't simply be thrown into the backyard mulch heap. There is little composting infrastructure in the US, however, with sites concentrated on the West coast.[69]

Limited feedstocks: Currently, there are few bio-based chemicals and supply is tight.[70]

Physical differences: Bioplastics' physical properties are not always the same as the polymers they replace. Differences could range from a slightly different texture to more jarring changes.[71] Pepsi subsidiary Frito-Lay discovered this the hard way in 2010, when it replaced its SunChips bags with much noisier compostable packaging. Customers ridiculed the bags' noise, comparing it to a "revving motorcycle" and "glass breaking"[72], and four months later the company rolled out a replacement compostable bag.[73]

Confusion over terms and standards: The public does not have a clear understanding of what bioplastics are, and this is made worse by conflicting definitions within the industry. For example, companies make biodegradability claims for some products that do not completely biodegrade under ASTM or European standards.[74]

[69] Ibid.

[70] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

[71] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[72] http://www.environmentalleader.com/2010/10/04/frito-lay-yanks-sunchips-compostable-bag-to-fix-noise-level/

[73] http://www.environmentalleader.com/2011/02/24/frito-lay-unveils-quieter-sunchips-bags/

[74] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

Ecological drawbacks: Bio-based plastics could cause some harm through acidification and eutrophication. Manufacturers must be sure that additional processing stages and additives do not introduce environmental burdens that outweigh the benefits of these materials.[75]

Food security and land use: Many bioplastics are made from crops that might otherwise be used for food, which could reduce land available for food production, or create incentive to cut down forests to create cropland. However, many types of biofuels avoid these problems, by using feedstocks unsuitable for human consumption, or by using land unsuitable for growing food.[76]

[75] Roland Essel, Nova-Institute, Meta-Analysis of Life Cycle Assessments for Bio-Based Polymers (PLA & PHA). 5th International Congress on Bio-based Plastics and Composites, Cologne, March 15, 2012.

[76] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

Policies and Programs

Some countries and cities have introduced bans on certain types of non-biobased or non-biodegradable plastics. In the US, there seems to be a trend for bans on non-biodegradable single use shopping bags, with several dozen US cities now instituting such rules.

For example:

China banned the production of bags thinner than 0.025 millimeters in 2008. It also prohibited supermarket and department stores from offering free plastic bags. A government official said that over four years, the ban saved 4.8 million metric tons of oil.[77]

Italy banned non-biodegradable, single-use shopping bags starting in 2012.[78]

San Francisco passed a pan on plastic bags in chain supermarkets and drug stores in 2007.[79]

Los Angeles approved a ban on plastic bags at supermarkets in 2012.[80]

Portland, Oregon banned most plastic bags.[81] From 2011 the ban applied to large grocers, and in 2013 it expanded to cover food providers over 10,000 square feet. In October 2013, it is set to expand again to cover all restaurants and food retailers.[82]

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[77] http://usa.chinadaily.com.cn/china/2012-06/20/content_15515599.htm

[78] Ibid.

[79] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[80] http://latimesblogs.latimes.com/lanow/2012/05/los-angeles-plastic-bag-ban-approved.html

Seattle put a plastic bag ban into effect in 2012.[83] The city has also introduced an ordinance requiring restaurants to only use bioplastics that will decompose in the city's composting plant.[84]

Standards and Certifications

A number of bodies have set standards and created product labels for bio-based and biodegradable plastics. Standards for renewable carbon content and compostability are now well established, and the global certification bodies in this area coordinate closely. Standards are emerging for marine, landfill and anaerobic digester biodegradation.[85]

USDA Certified Biobased: The US Department of Agriculture launched this voluntary certification and labeling program for industrial and commercial products in January 2011. The initiative is part of the USDA's BioPreferred program, which includes a biobased product preference for federal agencies.[86] But in January 2013, the USDA stopped processing applications for Biobased certification, due to a lack of funding. The

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[81] Ibid.

[82] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[83] http://www.kirotv.com/news/news/seattle-bans-plastic-shopping-bags/nPjsx/

[84] Ibid.

[85] Biome Bioplastics white paper, Bioplastics: an important component of global sustainability. http://www.biomebioplastics.com/uploads/files/white_paper.pdf

[86] http://www.environmentalleader.com/2011/01/20/usda-biobased-labels-debut/

agency says the 900 existing Biobased certifications in 89 categories will remain valid, and it will continue limited activities related to the federal product preference as staff resources allow.[87]

International Organization for Standardization: The organization developed ISO 17088 – Specifications for Compostable Plastics, as a global standard specification for biodegradability[88] in 2008, and revised the standard in 2012.[89]

ASTM International: The organization has a number of specifications and test methodologies for plastic end-of-life. These include:

ASTM D6400: Compostability of Plastics

ASTM D6868: Compostability of Plastic Coating on Renewable Substrates

ASTM D7081: Marine Biodegradability

ASTM D5338: Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions

ASTM D5511: Anaerobic Biodegradation of Plastic Materials Under High-Solids Anaerobic Digestion Conditions

ASTM D5988: Soil Biodegradability

ASTM D6691: Marine Biodegradation

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[87] http://www.biopreferred.gov/files/BioPreferred%20Program%20Status%20Jan%202013.pdf

[88] Ibid.

[89] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

ASTM D6854: Oxo-degradability of Plastic Additives

ASTM D6866: Biobased Carbon Content[90]

Biodegradable Product Institute (BPI): The organization runs a third-party, peer-reviewed certification for compostability, in partnership with NSF International.

Bureau of Normalization of Quebec: Certifies compostable products for the province under CAN/BNQ 0017-988, and compostable plastic bags under BNQ 9011-911/2007.

European Bioplastics Association: Governs certification using the European Norm (EN) 13432 – Packaging – Requirements for Packaging Recoverable Through Composting and Biodegradation – Test Scheme and Evaluation Criteria for the Final Acceptance of Packaging. This is similar to the ASTM D6400 and ASTM D6868 protocols.

Vinçotte: This Belgian organization developed the OK compost certification program, with separate standards for soil and water, and in 2009 launched a bio-based program.

Japanese BIoPlastics Association: Governs biodegradable standard GreenPla, which is harmonized with EN 13432.[91]

[90] Ibid.

[91] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

Latest Developments in Green Plastics

US and Global Markets

Bioplastics today account for a small proportion of total plastics usage - less than 1 percent by one estimate.[92] The worldwide bioplastics production capacity in 2011 was 1.16 million metric tons.[93]

The makeup of this market has shifted radically over just two years. In 2009, non-biodegradable bio-based plastics made up just 23,000 metric tons, or 9 percent, of the market. But by 2011 this had grown to 675,000 metric tons, or 58 percent.[94] These plastics' dominance will increase in coming years (see *Projections*).

North America has been a laggard in this field – with production capacity of 159,000 metric tons in 2011, compared to 402,000 in Asia, 381,000 in South America, 215,000 in Europe, and just 5,000 in Australia. In 2008, the US market was estimated at about $490 million.[95]

The North American market has, however, experienced significant growth with the development of more manufacturing plants, and brand owners' increased focus on sustainability is opening opportunities for bioplastics. The USDA's BioPreferred program has helped to promote bioplastics for federal procurement.

[92] Ibid.

[93] European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012. http://en.european-bioplastics.org/press/press-pictures/labelling-logos-charts/

[94] European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012. http://en.european-bioplastics.org/press/press-pictures/labelling-logos-charts/

[95] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

In contrast, bioplastics have been sold in Europe for over 20 years. Popular products there include compostable biowaste bags and loose fill packaging.

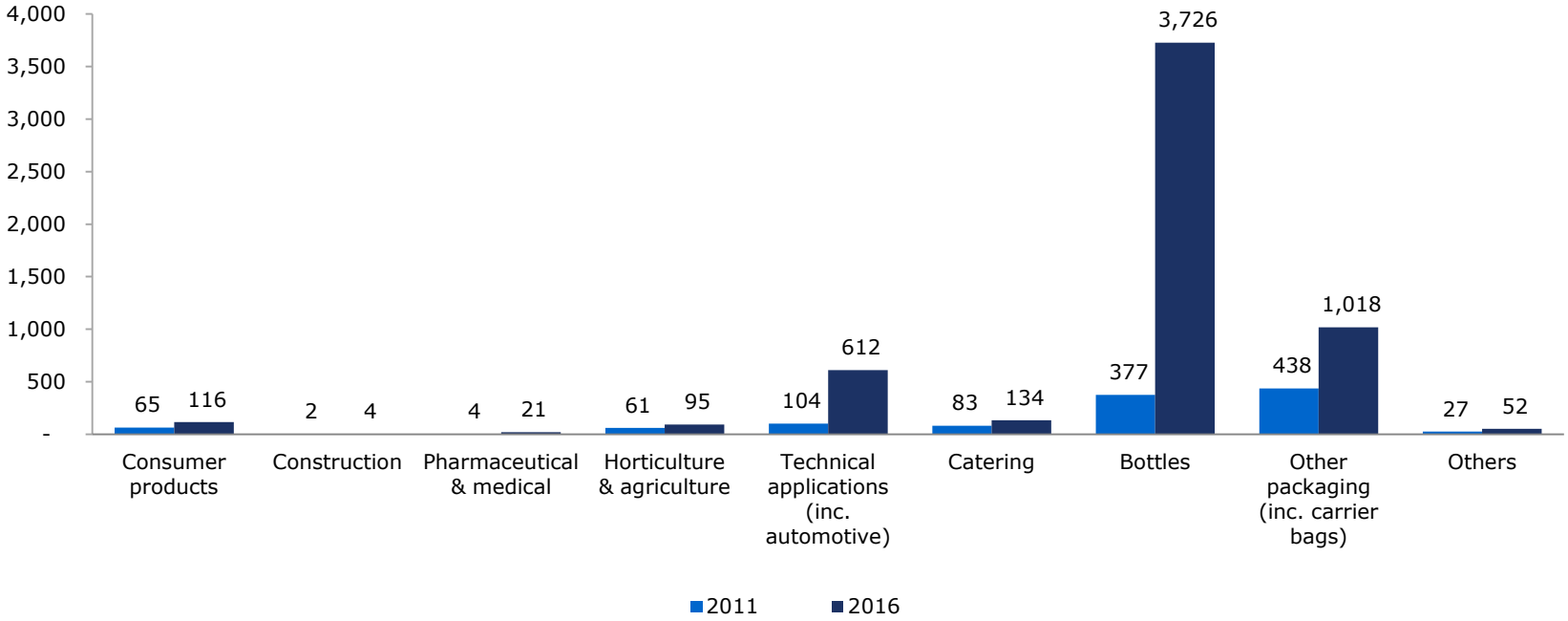
In Asia Pacific, many countries are instituting regulations to promote bio-based materials.[96]

Adoption by Businesses

Coca-Cola: The company introduced its PlantBottle, a PET container comprising up to 30 percent bio-based material, in 2009. It now uses the packaging in nine countries, including in the US, for Coca-Cola, Dasani,

[96] Ibid.

Global Bioplastics Production Capacity by Application,
2011 and 2016, thousand metric tons



Source: European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012

Vitamin Water and Sokenbicha products. The company aims to use only bio-based PET by 2020.[97] It plans to start using a wider variety of plants for its feedstocks, and is looking for ways to move to 100 percent bio-based PET.[98] Coca-Cola also uses a 100 percent sugarcane-derived HDPE bottle for its Odwalla smoothies.[99]

[97] http://www.coca-colacompany.com/stories/plantbottle-frequently-asked-questions

[98] http://www.coca-colacompany.com/stories/plant-bottle-basics

[99] http://www.odwalla.com/good-story/good-to-the-earth

Heinz: The company is one of several partners packaging its products using Coca-Cola's PlantBottle technology.[100]

Ford, Nike, Procter & Gamble: The companies have all partnered with Coca-Cola on its PlantBottle program.[101]

PepsiCo: In March 2011 the company announced what it called the first 100 percent bio-based PET bottle. The bottle is made of switch grass, pine bar, corn husks and other materials.[102] PepsiCo subsidiary Frito-Lay unveiled biodegradable bags for its SunChips in 2010, but replaced the bags in 2011 after customers said the packaging was too noisy.[103]

Danone: Volvic brand water launched a 20 percent sugarcane PET bottle in 2010.[104]

Toyota: The company announced a 30 percent bio-based polyester carpet and interior trim, to be used on an electric hybrid car for the Japanese market.[105]

AT&T: The company announced it would use up to 30 percent bio APET clamshell packaging, made by Display Pack from Klockner Pentaplast's TerraPET sheet, for its cell phone accessories.[106]

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[100] http://www.environmentalleader.com/2011/02/24/heinz-adopts-coca-cola-plantbottles/

[101] http://plasticsengineeringblog.com/2012/08/13/the-race-to-100-bio-pet/

[102] http://www.environmentalleader.com/2011/03/15/pepsico-unveils-100-bio-based-rival-to-cokes-plantbottle/

[103] http://www.environmentalleader.com/2011/02/24/frito-lay-unveils-quieter-sunchips-bags/

[104] http://www.environmentalleader.com/2010/09/20/volvic-greener-bottle-made-from-20-sugarcane-waste/

[105] Ibid.

[106] http://plasticsengineeringblog.com/2012/08/13/the-race-to-100-bio-pet/

The Future of Green Plastics

Projections

Global bioplastics capacity is projected to grow almost five-fold by 2016, to 5.78 million metric tons, but with wide regional disparities. Asia and South America will take the lion's share of growth, while North America will see more modest gains, from 159,000 metric tons in 2011 to 202,000 in 2016 (see chart).[107]

Asia and South America's advantage is due to their access to feedstock and favorable political framework. But in the bio-based market specifically, Nova-Institute does not expect world market shares to shift dramatically.[108]

Bio-based, non-biodegradable plastics will increase their share, coming to take 87 percent of the market by 2016.[109] Bio-based's share of polymer production will grow from 1.5 percent in 2011 to 3 percent in 2020.[110]

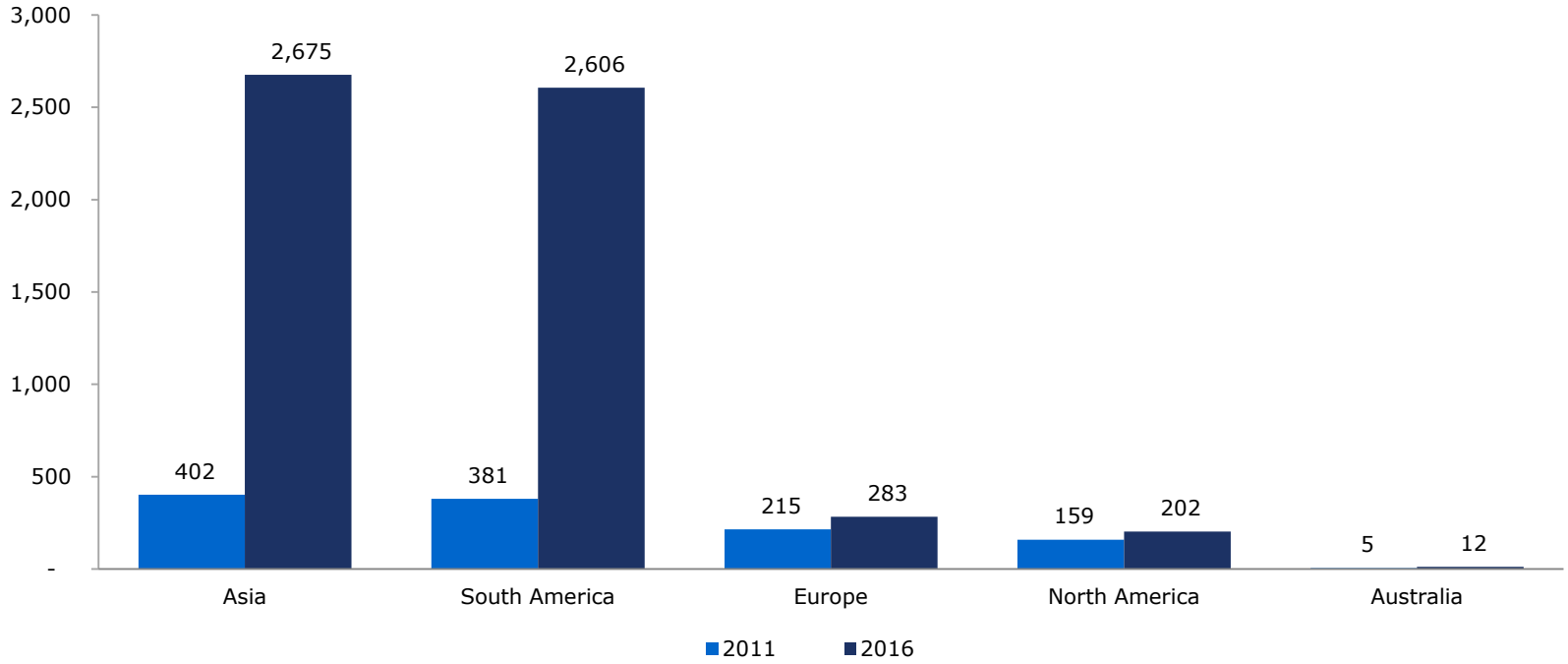
[107] Ibid.

[108] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

[109] European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012. http://en.european-bioplastics.org/press/press-pictures/labelling-logos-charts/

[110] Market Study on Bio-Based Polymers in the World. Nova-Institute, March 2013. http://www.bio-based.eu/market_study/media/files/13-03-26MarketStudyLeaflet.pdf

Global Bioplastics Production Capacity by Region,
2011 and 2016, thousand metric tons



Source: Environmental Leader calculations, April 2013, based on European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012

The Nova-Institute predicts that production capacity for bio-based polymers will triple from 3.5 million metric tons in 2011 to nearly 12 million metric tons in 2020. This figure includes not just bioplastics but bio-based rubber and fibers. It predicts that drop-in PET, PE/PP, PLA and PHA will see the fastest rates of market growth, with PLA and PHA at least quadrupling capacity.[111]

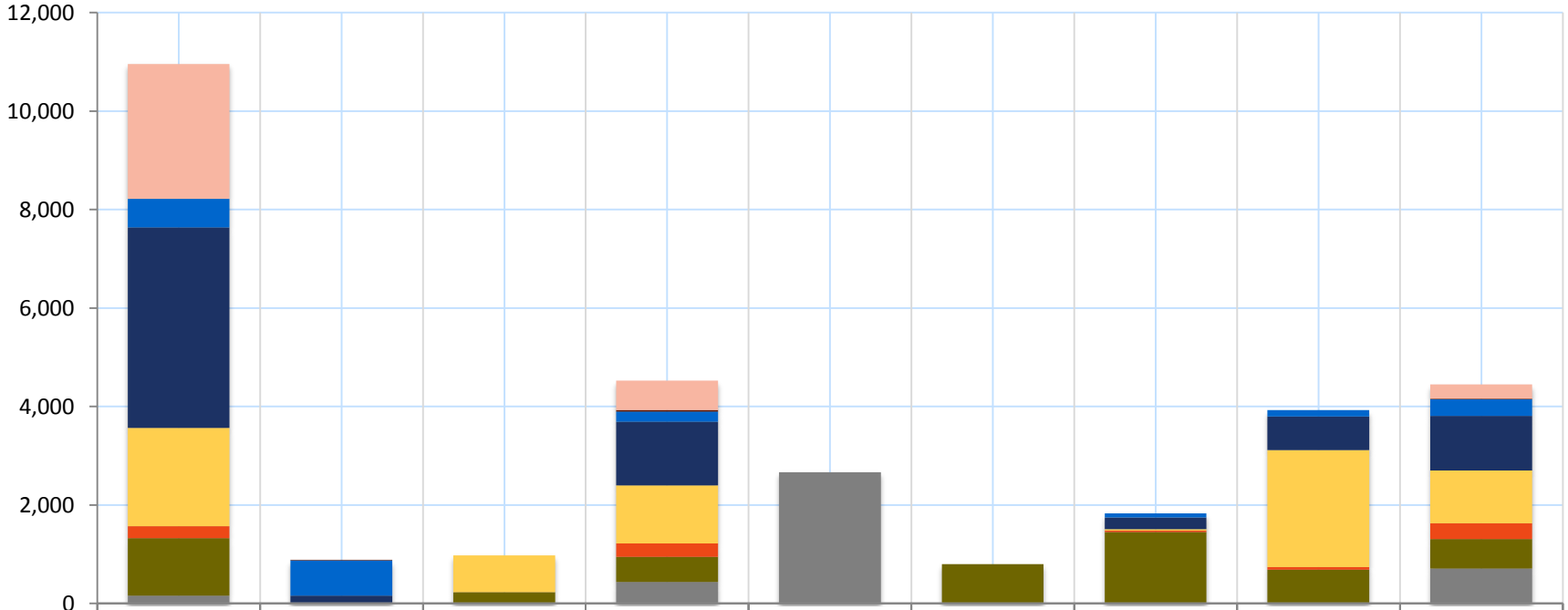
Bio-PET is expected to completely dominate the growing market, with production capacity of 4.6 million metric tons in 2016, or 80 percent of the total bioplastics market in that year.[112]

[111] Ibid.

[112] European Bioplastics / Institute for Bioplastics and Biocomposites, October 2012. http://en.european-bioplastics.org/press/press-pictures/labelling-logos-charts/

Plastics in Products in Municipal Solid Waste, 2010

Thousand tons



	All	Plates and cups *	Trash bags	All other nondurables	Bottles and jars**	Bottles - white translucent homopolymer	Other plastic containers	Bags, sacks and wraps	Other plastics packaging
	DURABLE GOODS	NON-DURABLE GOODS			PLASTIC CONTAINERS & PACKAGING				
Other resins	2,740			600					290
PLA		10		30					10
PS	580	720		210			80	130	340
PP	4,070	140		1,290			240	680	1,110
LDPE/LLDPE	2,000	20	750	1,180			30	2,380	1,070
PVC	240			270			30	50	320
HDPE	1,170		230	510		800	1,450	690	600
PET	160			440	2,670				710

* Due to source data aggregation, PET cups are included in "Other Plastic Packaging".

** Injection stretch blow molded PET containers.

Source: Franklin Associates, A Division of ERG, via EPA

The industry continues to innovate, however, meaning new polymers could reach markets shortly. This will help grow the overall market, as will the addition of new producers.[113]

The charts on overall plastics consumption and disposal *(please see pages 21 and 35)* show where opportunities exist for further innovation in bioplastics. So far, bio-based plastics have had relatively little penetration into durable goods, and this makes up a sizable proportion of total plastics use. In addition, across almost all material and application categories, landfill rates remain at or close to 100 percent – suggesting opportunities both for recycling and for biodegradable plastics.

Green Plastics: What does all this mean?

- The bioplastics market is increasingly dominated by bio-based materials, which are not necessarily biodegradable.
- This is a market where one big purchaser can change the entire landscape.
- Further disruptions could come in the form of new plastics.
- Growth prospects look good, and as capacity grows costs should come down.
- There are concerns about the ability of the US recycling infrastructure to handle these materials.

[113] Bioplastics Industry Overview Guide, Executive Summary, The Society of the Plastics Industry, Bioplastics Council. September 2012. http://www.plasticsindustry.org/files/about/BPC/Industry%20Overview%20Guide%20Executive%20Summary%20-%200912%20-%20Final.pdf

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Q&A

Phil Ragan, Director of Market Development, EcoSafe Zero Waste

Environmental Leader: What type of green plastics do you use? Please give both the generic and trade name.

We use a blend of the BASF resin "ecovio" combined with PLA (corn starch). We market our retail and commercial BPI Certified Compostable Liners under the "EcoSafe~6400®" brand.

What do you use them for?

EcoSafe~6400 liners are a very high quality liner for small bins and large commercial carts and are used for the collection of organic waste including food scraps, green waste and commercial waste such as pig afterbirths and chicken mortalities.

Why did you choose these materials in particular – did it have certain properties that fit your needs?

We have been in the biodegradable plastics business for more than a decade and part of our business practices is to monitor and test resins from all over the world as they are developed. We have chosen the BASF bio-based compostable resins for their superior performance and the willingness of our suppliers to work with us in a very competitive marketplace. While we will stay diligent to our mission to ensure we are on the leading edge for price and performance, we are confident that our supplier partners will be there as strategic partners to adjust to any new developments.

What are the benefits to you, and to your customers, in using bioplastics?

BPI Certified Compostable products enable compostable wet waste to be source separated and diverted from landfill to composting facilities as part of the new “resource recovery” model that supports the long term sustainability of our planet.

How do the properties of green plastics compare to their conventional counterparts?

Great strides have been made over the last decade but even more over the last two years as we have moved very close to parity with ordinary plastics.

How do the costs compare?

Still too high but economies of scale and increased performance at lighter gauges is tilting the trend downward.

Can manufacturers using bioplastics recoup the increased cost of these materials by charging a premium to customers? Does this usually succeed, or are customers put off by the increased price?

Sticker shock was at one time a problem but today is generally accepted; the decision to use “certified compostable” food service wares and bags is usually determined by the economics of disposal. If landfill disposal fees are high relative to organics collection for composting it is an easy sell; if not, it can be a challenge.

What do you think are the biggest untapped markets for green plastics?

Food services, though I wouldn’t characterize it as “untapped” as much as they are in development with a lot of room for growth.

What types of manufacturers should consider replacing their current materials with green plastics? Certain sectors, companies using certain resins, certain geographies?

Manufacturers of food service wares will all over time replace traditional plastic wares with PLA, paper or other fiber-based compostable materials. In the bag segment there are already sufficient suppliers in the market. Compostable plastics are not a replacement for ordinary plastics; only products that support a specific function in the collection of compostable organic waste with an “end of life” in a commercial compost facility should be converted. The end-of-life for ordinary plastics is recycling… not as landfill.

What are the difficulties in manufacturing with green plastic? What hurdles must be overcome?

Manufacturers of compostable film products quickly learn that bio-plastics are not PE or PP; the processing profiles are different and experience and “know-how” play a big part in producing a premium product.

I’ve read that tight supplies are an issue in the bioplastics market. Has that been a challenge for you, and if so how did you overcome it?

There is now sufficient capacity to supply the existing market. I do not anticipate any shortages in the near to mid-term.

What trends do you see in the bioplastics industry, and how do you see the market evolving over the next few years?

Separating “bio-based” products from “compostable” products: bio-based will become more and more important as we move to more sustainable materials that are not necessarily “plastic”; many will be fiber based. I will also point out that like aluminum cans, high value recyclable materials such as PET contribute to a more sustainable economy if the recycling infrastructure is in place. Product such as razors, pens and bottles made with biopolymers are of little benefit to the environment unless there is a specific “end of life” plan other than as landfill. Products not relating to food services will never be composted. Compost facilities are not alternatives to landfill unless the product is organic or contributes to increasing collection volumes of organics without contaminants.

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