Rubber & Synthetic Biology

A Case Study

Tapping a rubber tree. *photo: Dhruvaraj S*

Product: Rubber is the tropical plant-derived product receiving the most attention from synthetic biology companies. Several labs are working to scale up production of biosynthetic isoprene, as well as butadiene and isobutene, all components in the manufacture of synthetic rubber. The goal is to manufacture commercial-scale quantities that will compete with both natural and synthetic rubber.

Status: Several commercial teams are using synthetic biology to manufacture isoprene in microbial cell "factories" via fermentation; DuPont and Goodyear have already produced a prototype tire using biosynthetic isoprene. France-based Global Bioenergies has produced both bio-butadiene and bio-isobutene using engineered metabolic pathways in bacteria. In May 2012, Bridgestone announced joint development of synthetic rubber made from isoprone with the the Japanese company Ajinimoto.

Affected Country/Region: 20 million smallholder families rely on rubber trees (*Hevea brasiliensis*) for their livelihood. The rubber industry in Southeast Asia is characterised by the preponderance of small farmers who own and cultivate some 67 percent of the total planted area in Malaysia, 78 percent in Indonesia, 95 percent in Thailand and 65 percent in Sri Lanka. Most of the smallholdings are less than 10 acres apiece and are widely scattered. Cambodia, China, India, Indonesia, Malaysia, Papua New Guinea, Philippines, Singapore, Sri Lanka, Thailand and Vietnam accounted for about 93% of the global production of natural rubber during 2013. The global market for natural rubber was approximately $35 billion in 2010. In 2012, the total area dedicated to natural rubber production in the world was 9.56 million hectares.

Market: Current demand for isoprene: 850,000 tons per year, with a market value of $2 billion. (The demand is likely to grow faster in 2014; Demand for natural and synthetic rubber will hit 27.7 million tonnes this year.

Commercialization: Products are either on the market or will be imminently as of 2014.

About Rubber

Rubber is the tropical, plant-derived product receiving the most attention by synthetic biology companies. A major focus is *isoprene* – the molecule that is a crucial building block for making synthetic rubber. The gene encoding *isoprene* has been identified only in plants such as rubber trees. In 2010, DuPont subsidiary Genencor announced that it had used synthetic biology to produce "BioIsoprene." Its goal is to manufacture BioIsoprene cheaply and in commercial-scale quantities via fermentation to compete with both natural and synthetic rubber.

Asia is by far the largest producer of natural rubber. In 2013, global natural rubber production was 12 million metric tons (MT). Five Asian countries accounted for 83% of all natural rubber produced worldwide. According to the International Rubber Study Group 80% of all natural rubber is produced by small holders who farm an average 1 to 2 hectares. Globally,

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Rubber and Synthetic Biology
A New and Emerging Issue for CBD

This case study illustrates recent developments in synthetic biology that could impact the $35 billion natural rubber market and disrupt the livelihoods of producers. These developments impact the sustainable use of biodiversity and fair and equitable sharing of benefits from the genetic resources associated with rubber production. Natural rubber has already lost half of its market to petroleum-based synthetics. If production challenges are resolved, production via synthetic biology could erode the remaining half. Using synthetic biology, three different commercial teams are working to produce a biosynthetic isoprene that could soon impact Asia's exporters; other companies are producing biosynthetic butadiene and isobutene, also crucial to the manufacture of rubber. Today, more than 60 percent of all natural rubber is used for tires with replacement tires accounting for the majority. Rubber is just one of hundreds of economically important natural plant compounds whose production may be switched to synthetic biology production in a very short time frame. The Convention on Biodiversity is the only intergovernmental body addressing the potential impacts of synthetic biology on the conservation and use of biodiversity and on the livelihoods of those who depend on agricultural export commodities (including high-value flavors, fragrances, essential oils, etc). It is the most appropriate forum to address this new and emerging issue.

an estimated 20 million small holder families rely on natural rubber for their livelihoods.

Current R&D

Synthetic rubber is typically made from chemical synthesis of petroleum-derived isoprene. Companies are now competing to develop the most efficient metabolic pathway for producing a cheaper version of isoprene via biosynthesis in engineered microbes. Global Bioenergies is developing bio-based isobutene and is collaborating with Poland-based rubber manufacturer Synthos to commercialize bacterial biosynthesis of bio-butadiene. The goal is to reduce the tire industry's dependence on petroleum-derived synthetic rubber, and, perhaps, to capture some portion of the market for natural rubber.

> ***"The BioIsoprene process being pioneered by Goodyear and Genencor finally offers the very real possibility for obtaining the quantities of low-cost isoprene needed to produce a meaningful large-volume alternative to Hevea natural rubber."***
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> – Frank J. Feher, *Rubber & Plastic News*, November 1, 2010.

The tire industry is the driving force behind changes in demand for natural rubber. Although natural rubber is more easily replaced by synthetics in non-tire applications, natural rubber is still a vital – and thus far irreplaceable – component in tires. More than 60 percent of all natural rubber is used for tires, and the content of tires is typically 50% natural rubber.

BioIsoprene has already been used to manufacture prototype tires: According to a report in Industrial Biotechnology, "Current state-of-the-art technology has resulted in production, recovery, polymerization, and manufacture of tires with the isoprene component produced via fermentation. Continued improvements in both the cell factory and the production process are being actively pursued."

It is too early to predict if bio-isoprene has the potential to capture a portion of the market for natural rubber. But scientists who are working on BioIsoprene indicate that the product "has the potential to provide a large-volume alternative to Hevea natural rubber and petroleum-derived isoprene."

Top 5 Natural Rubber Producers (end of 2012)

Country	Natural Rubber Production (millions of MT)
Thailand	3.6
Indonesia	3
Malaysia	0.95
India	0.9
Vietnam	0.9

Source: (Natural Rubber Industry Vietnam).

For More Information

ETC Group has published several documents explaining and analyzing the impact of Synthetic Biology on biodiversity and livelihoods including *Extreme Genetic Engineering - An introduction to Synthetic Biology*, *The New Biomassters - Synthetic Biology and the Next Assault on Biodiversity and Livelihoods* and *The Principles for the Oversight of Synthetic Biology* available on our website: www.etcgroup.org/issues/synthetic-biology

The Potential Impacts of Synthetic Biology on the Conservation & Sustainable Use of Biodiversity: A Submission to the Convention on Biological Diversity's Subsidiary Body on Scientific, Technical & Technological Advice (A Submission from Civil Society) www.etcgroup.org/en/node/5291

References

For a list of sources cited in this document, email *info@etcgroup.org*.

photo: Yun Huang Yong

Intellectual Property related to Isoprene Rubber Pathway Engineering:

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EP1364005B1: A Method for Evolving a Cell Having Desired Phenotype and Evolved Cells. Evolva AG. 17 Sept 2008.

WO2011146833A1: Method of Producing Isoprenoid Compounds in Yeast. Evolva. 24 Nov 2011.

Several commercial teams are using synthetic biology to manufacture isoprene in microbial cell factories via fermentation:

Genencor (now owned by DuPont) has been partnering with **Goodyear Tire & Rubber** since 2007 to develop BioIsoprene. Genencor predicts that its product will reach the commercial market in 2013. Prototype tires containing BioIsoprene have already been unveiled.

In September 2011 **Amyris, Inc.** announced a partnership with French tire manufacturer **Michelin** to develop and commercialize isoprene. Amyris expects to begin commercializing its isoprene in 2015 for use in tires and other specialty chemical applications such as adhesives, coatings and sealants.

In May 2010, **Texas-based GlycosBio** announced a collaboration with **Malaysia's Bio-XCell** to build a biorefinery with a planned 20,000 tonne/year capacity to produce isoprene using glycerine (derived from oil palm) as a feedstock. The company plans to produce bio-isoprene for commercial rubber applications in 2014. The 161-acre biotechnology park in Malaysia is already in line to receive investments worth $80 million from firms like Biocon and Strides Arcolab from India; Metabolic Explorer from France; and GlycosBio.

Japanese chemical manufacturer Kuraray has created a liquid rubber based on **Amryis'** farnesene, which it aims to use in tires. The new biorubber is currently being tested by tire manufacturers in Japan and overseas. Kuraray's liquid rubber business already includes liquid isoprene rubber and liquid butadiene rubber, but this is the first biorubber the company has produced. The two companies have expressed their intent to extend the current 2011–2014 agreement for two additional years.

In May 2012, **Bridgestone** announced its joint development of synthetic rubber made from isoprene with **Japanese company Ajinomoto**.As a next step in the process, the Bridgestone Group will establish a framework of research and development and initiate the necessary core technologies to begin mass production.