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Review

# A sustainability review of domestic rubber from the guayule plant

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ABSTRACT

Guayule (*Parthenium argentatum* Gray) is an arid-adapted, low-input perennial shrub native to Mexico and southern Texas that has received considerable attention as an alternative source of natural rubber. It has potential to replace the most common types of rubbers, including synthetic rubber derived from petroleum and natural rubber, which is tapped from Hevea (*Hevea brasiliensis*) trees grown in tropical regions, primarily Southeast Asia. The guayule plant produces natural rubber in its bark parenchyma cells and the shrub is processed to extract the latex. Guayule rubber is comparable in quality to Hevea natural rubber and the residual, non-latex guayule plant material can be transformed into valuable co-products, such as bioenergy. This review introduces the reader to guayule rubber production (agriculture, processing and products) and explores the sustainability implications of guayule rubber commercialization related to the three pillars of sustainability, including environmental impacts of rubber production, economic barriers and advantages, and social implications. The review highlights areas of focus that could be leveraged to help guayule become a more sustainable source of natural rubber. Guayule rubber provides an opportunity to lower the environmental impacts of a major commodity, to develop an industry to support the local U.S, economy, and to reduce U.S. dependence on non-renewable petroleum sources and rubber imports. Proposed recommendations to further support guayule sustainability include improving the efficiency of agricultural and processing activities, utilization of guayule co-products to improve economics of guayule cultivation, and the establishment of a secure guayule rubber supply at a production level that could consistently meet rubber demands. A better understanding of guayule rubber life-cycle impacts could be a way to reduce the environmental footprint of guayule rubber products and expedite its commercialization.



**Contents**



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## 1. Introduction

The U.S. uses rubber in a wide range of products, from tires to medical products; in 2013 U.S. industry consumed 2.7 million metric tons of rubber (IRSG, 2013). The most common elastomers are synthetic rubber derived from petroleum and natural rubber from Hevea (*Hevea brasiliensis*). Most synthetic rubbers are imported from Republic of Korea and China (United Nations Statistics Division, 2014), while natural rubbers are imported from Thailand, Indonesia and Vietnam. In 2013, world production of natural rubber reached 12 million metric tons (ISRG, 2014) and the U.S. imported approximately $4.6 \times 10^4$ metric tons of natural rubber (United Nations Statistics Division, 2014), mainly from Asia where over 90% of the world's natural rubber production occurs (van Beilen and Poirier, 2007b). Substantial amounts of petroleum-based synthetic rubber is produced in the U.S. every year (approximately 3 million tons (IRSG, 2014)). Synthetic rubber costs are dependent on petroleum price, which are known to have been unstable in the past and are predicted to remain unstable in the future. The production of synthetic rubber requires high energy use compared to Hevea natural rubber (UNCTAD and IRSG, 1997), and is environmentally intensive due to non-renewable fossil fuel use.

The guayule plant (*Parthenium argentatum* Gray), shown in Fig. 1, produces natural rubber in its bark parenchyma cells and has the potential to substitute rubber from petroleum and Hevea imports in the U.S. Guayule is a woody perennial shrub native to Mexico and the Chihuahuan desert of southern Texas. It can be grown on semi-arid lands, for example in the Southwestern U.S., that are unsuitable for major crops (Malik and Singh, 2006) and can bring retired lands back into profitable production (Cornish and Siler, 1996b). It is an industrial crop that is not a food crop (Lane, 2013), and it is easily mechanized and not labor intensive (Nakayama, 1992). Guayule typically requires less nutrients than traditional U.S. agricultural crops (Foster and Coffelt, 2005) and requires little or no pesticide application (Herman, 2004). Guayule has the benefit of being a low input crop (Rodríguez-García et al., 2002), which could potentially qualify it as a sustainable substitute for Hevea natural rubber. It is comparable in quality to Hevea rubber (Cornish et al., 2008) and although the latex does not yet compete directly with the less expensive Hevea rubber for tire production, it does compete with the more expensive synthetic latex and Hevea latex in the medical device market (Cornish and Siler, 1996b; Coffelt and Ray, 2010). Guayule rubber could reduce U.S. dependence on rubber imports from Southeast Asia and on non-renewable petroleum sources. Furthermore, the residual, non-latex guayule plant material can be transformed into valuable co-products, such as biofuels (e.g., ethanol, bio-oil, syngas, biochar), paper pulp, composite boards, natural wood preservatives, insulation, compressed logs or pellets for burning and activated carbon (Nakayama, 2003, 2005; Chow et al., 2008; Boateng et al., 2009; Wood, 2009; Holt et al, 2012).

To date, several studies are available on the agronomy (Ray, 1993; Foster and Coffelt, 2005), future development (Nakayama, 2005) and commercialization of guayule (Foster et al., 1991; Cornish and Siler, 1996b; Ray et al., 2005; EU-PEARLS, 2013). There are no sustainability assessments or publicly available life cycle assessments on guayule or guayule rubber products. This paper aims to review the sustainability of guayule-derived rubber with a comparison to Hevea, including the agriculture and biomass and rubber yields, and to synthetic rubbers.

**Fig. 1.** Guayule Plant in the U.S. (Soratana, 2013).

## 2. Pillars of sustainability

Sustainability was described by the International Institute of Environment and Development as socially desirable, economically viable and ecologically sustainable (Bass et al., 1995; Taticchi et al., 2013); in practice this is referred to as the triple bottom line or the three pillars of sustainability. While economic feasibility is well understood, social dimensions are most difficult to quantify and may be problematic and subjective. Social sustainability can address issues such as living and working conditions, income, cultural implications and livelihoods. Lastly, environmental dimensions of sustainability are focused on minimizing harm to the environment and reducing the ecological footprint through managing materials usage, energy consumption, waste and ecologically destructive practices.

## 3. Guayule rubber production

This study presents a review of the sustainability related to U.S. production of guayule rubber. First, this review summarizes