From Balsa Wood to Polymer Foam in Wind Turbine Blades: Material Input Substitutes in Low-Carbon Technologies

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Wind is a low-carbon energy source integral to global climate policies and decarbonization efforts. Construction of wind generating turbines requires many material inputs: balsa wood—a frequently used input in the core of wind turbine blades—is an important example. Balsa—which is chiefly produced in and exported from Ecuador—has, however, recently suffered from supply shortages, illegal logging, and deforestation. In response, wind turbine original equipment manufacturers (OEMs) are adapting by increasingly substituting balsa wood with synthetic polymer foam (a type of what is colloquially called plastic). This EBOT discusses this example of material input substitution in low-carbon technologies.[1]

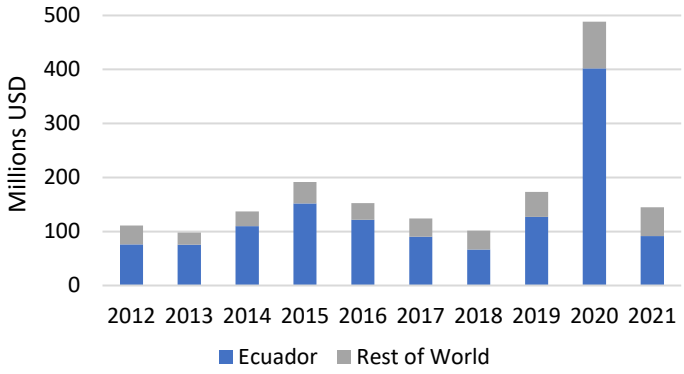
Growth in wind energy

The International Energy Agency (IEA) estimated that wind installations generated 1,870 terawatt-hours (TWh) of electricity globally in 2021, a new wind energy record. The 2021 total was an increase of 17 percent from 2020; since 2010, wind installation electricity generation has increased by a factor of 5.5 (over 445 percent). China and the United States continue to dominate wind power production, accounting for 84 percent of wind generation growth in 2021.[2]

Of blades and balsa

Wind turbines consist of thousands of parts which can be divided into six major components: foundation, tower, blades, hub, generator, and nacelle. The blades, which usually total three, must be lightweight and strong. Blade designs are generally based on glass- or carbon-fiber reinforced composites. Typically, a blade's core is constructed with balsa wood or polymer foam. The balsa tree is native to the tropical Americas, ranging from southern Mexico to Peru. Because balsa is scattered in forests amidst other tree species, much of its commercial harvesting is done in balsa plantations. A fast-growing tree, balsa is lightweight compared to other wood species while also being strong; it is thus ideal for wind turbine blades.

Figure 1 Global balsa wood exports, value (dollars), 2012–21



Source: S&P Global, Global Trade Atlas database, HS-6 subheading 4407.22, accessed August 1, 2022.

Ecuador's balsa exports

Ecuador is the largest global balsa producer and exporter (figure 1). Between 2012 and 2021, Ecuador accounted for on average 74 percent of all global balsa exports by value. China is the dominant destination for balsa exports, as it has been reliant on substantial imports as inputs for its growing wind turbine manufacturing and deployment.

Ecuador's exports of balsa have been relatively stable, except for 2020, when it rose to $402 million from $127 million in 2019, a 217 percent increase. The 2020 surge was almost entirely due to exports to China

[1] Low-carbon technologies are products deployed for climate change mitigation purposes.

[2] In 2019 (the most recent year with complete data for all energy sources), wind energy accounted for 5 percent of all globally generated electricity; fossil fuels (coal, gas, and oil) accounted for 63 percent.

(U.S. balsa imports have declined each year since 2018). The China growth was due to soaring Chinese demand for wind turbine inputs as well as anticipation of the coming lapse of Chinese subsidies for wind energy in 2021.

To meet Chinese demand, there was reportedly an upsurge of illegal balsa logging activities in Ecuador in 2020. *Primicias*, an Ecuadorian newspaper with access to data from Ecuador's Ministry of Environment, estimated that the quantity of illegally sourced balsa seized in Ecuador increased from 700 cubic meters in 2019 to 1,973 cubic meters in 2020, a 180 percent increase. Loggers reportedly exploited protected reserves to harvest balsa, especially lands belonging to the indigenous Waorani people living in Ecuador's eastern Amazon region. In addition, some of Ecuador's balsa exports were reportedly smuggled from Peru. Although official statistics reflected a major drop in balsa exports from Peru (86 percent between 2012 and 2020), Peruvian Customs has stated that Peruvian balsa has extensively been transported across the Peru-Ecuador border and then exported. Like Ecuador, Peru has a long history of illegal logging and related trade, deficient forest law enforcement, and deforestation.

In 2021, Ecuadorian balsa exports (especially to China) reverted to normal levels. This likely occurred because of slowing Chinese demand, higher balsa prices, and scarcer supply in Ecuador due to overlogging and harvest yields dampened by unusually heavy rains.

Polymer foam substitution growing

OEMs are increasingly using polymer foam as a substitute material input in blades. Polymer foam is durable, lightweight, and strong, and because it can be manufactured, it is more easily obtainable than naturally occurring balsa. Originally, most polymer foam used in blades was PVC (polyvinyl chloride), but PET (polyethylene terephthalate) has emerged as the preferred resin; experts cite its higher temperature resistance and its comparative ease of recycling. Wood Mackenzie, a consultancy, reported that balsa shortages have prompted OEMs to increase use of PET and forecasted that "the share of PET" [in blade cores will] "increase from 20 percent in 2018 to more than 55 percent by 2023."[3]

Material input substitution in low-carbon technologies

Manufacturers often seek material input substitution when advantageous or required by regulations. For instance, the shift to polymer foam for blade construction may alleviate some of the tribulations posed by balsa. Like most material inputs, however, polymer foam is not perfect: current production of polymer foam is derived from hydrocarbons (fossil fuels).

Sources: Argus, "Ecuador Balsa Wood Exports for Wind Turbines Decline," July 13, 2022; Cooperman et al., "Wind Turbine Blade Material," 2021; David, "The Evolution of Global Onshore Wind Turbine Blade Production," May 2021; The Economist, "The Wind-Power Boom Sets Off a Scramble for Balsa Wood in Ecuador," January 30, 2021; Dempsey and Long, "Balsa Shortage Threatens Wind Power Rollout," November 11, 2019; IEA, "Wind Electricity," September 2022; IEA, "World Gross Electricity Production by Source, 2019," August 6, 2021; Jones and Ramírez, "Timber Mafias at Ecuador's Border Cash in on Balsa Boom," June 21, 2021; McKibben, "In a World on Fire," March 18, 2022; Sellier and Ashton, "Evolution of Technologies and Materials," October 2017; Sørensen et al., "Blade Materials," 2010; Thomsen, "Sandwich Materials for Wind Turbine Blades," 2009; Wilburn, "Wind Energy in the United States," 2011; USITC, "U.S.-Peru Trade Promotion Agreement Annex," June 2021; Wood Mackenzie, "Global Wind Turbine Supply Chain Trends 2020," 2019; Worldwind Technology, "A Double-Edged Blade," July 27, 2021; Zunino et al., "Gone with the Wind," June 2022.

[3] Wood Mackenzie, "Global Wind Turbine Supply Chain Trends 2020," 2019.