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# The Rise of Utility Wood Pellet Energy in the Era of Climate Change

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# Abstract

Utility wood pellets (wood pellets) are a densified biomass fuel that can generate electricity or heating when burned. Production, consumption, and trade of wood pellets have grown substantially since the late 2000s in a small number of countries. The locus of consumption growth is industrial power plants where wood pellets are frequently used for co-firing with, or replacement of, coal. The catalytic factors for the robust wood pellet expansion have been European Union (EU) climate change policies and incentives, particularly designating the product as a 'renewable energy,' assessing their carbon emissions as zero, and providing financial support. The United States, with its sizeable forests and timber plantations, reacted by intensifying wood pellet production for export, primarily to the United Kingdom and several EU member states. In 2021, U.S. wood pellet exports reached $1 billion for the first time. Wood pellet consumption is also rising in Asia with South Korea and Japan, driven by their own climate change policies, incentivizing rapid recent growth in imports. This paper examines the rise of wood pellets as an alternative energy source and traded commodity in the era of climate change.

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# Introduction

Utility wood pellets (wood pellets) are a densified biomass[1] fuel that can generate electricity or heating when burned. Production, consumption, and trade of wood pellets have grown substantially since the late 2000s in a small number of countries. The locus of consumption growth is industrial power plants where wood pellets are frequently used for co-firing with, or replacement of, coal.[2] The catalytic factors for the robust wood pellet expansion have been European Union (EU) climate change policies and incentives. The United States, with its sizeable forests and timber plantations, reacted by intensifying wood pellet production for export, primarily to the United Kingdom[3] and several EU member states (especially the Netherlands, Denmark, and Belgium). Wood pellet consumption is also rising in Asia with South Korea and Japan, driven by their own climate change policies, incentivizing rapid recent growth in imports, mostly from Vietnam, Malaysia, and Canada. This paper examines the rise of wood pellets as an alternative energy and traded commodity in the era of climate change.

# Wood Pellet Production and Consumption

Wood pellets are small, consistent in size, wood-derived, compressed cylinders (figure 1). The raw material feedstock for manufacturing wood pellets can be generally categorized as roundwood (wood in its natural state when felled),[4] tree parts (e.g., branches), and forestry residues (waste such as sawdust) from forest product industry processes.[5] Although analysts are researching the proportions of these feedstock categories, there is not a clear consensus especially as there is widespread disagreement on industry terms and because practices vary significantly country to country.[6] Industry documents and research, however, reflect that a majority of wood pellet feedstock comes from trees and tree parts (roundwood, tree parts, and thinnings) and a smaller amount comes from forestry residues.[7]

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[1] Biomass is organic material from plants or animals and can be used as fuel. Sources for biomass include wood, agriculture, biogenic materials in municipal waste, and human or animal waste. Although usually a solid, biomass can be converted to liquids or gases. U.S. EIA, "Biomass Explained," accessed February 17, 2022.

[2] Most global trade in wood pellets is believed to be associated with their use in commercial scale electricity generation and combined heat and power (CHP). Such wood pellets are often referred to as 'utility pellets' or 'industrial pellets.' There is also a tiny market and volume of trade for wood pellets for use in residential and other small scale heating applications. These wood pellets are often referred to as 'heating pellets,' 'premium pellets,' or 'residential pellets.' Utility pellets have a higher ash content than heating pellets; pellets with high ash content may have adverse impacts on wood pellet stoves and air quality. U.S. EIA data reflects that the vast majority of U.S. produced wood pellets are utility pellets. See U.S. EIA, "New EIA Survey," December 14, 2016; U.S. EIA, "Monthly Densified Biomass," accessed February 16, 2022. This paper focuses solely on trade in 'utility pellets' used for electricity generation and CHP.

[3] The United Kingdom exited the EU on January 31, 2020. U.S. EIA, "Monthly Densified Biomass Fuel Report," accessed April 19, 2022.

[4] Brandeis and Abt, "Roundwood Use by Southern Wood Pellet Mills," 2019, 427–428.

[5] In academic, government, and industry documents, there is a wide divergence on the meaning of 'forestry residues.' This paper considers forestry residues to be the waste from industrial processes (such as papermaking and lumber production).

[6] Kittler, Stupak, and Smith, "Assessing the Wood Sourcing Practices," December 2020, 3.

[7] Brack, "Woody Biomass for Power and Heat," February 2017, 21–23; RISI, "An Analysis of UK Biomass Power Policy," 2015; Enviva, "Leading in Sustainable Wood Biomass," accessed April 19, 2022; Drax, "Annual Report 2020," March 5, 2021, 54. Drax, "Drax LaSalle BioEnergy Wood Pellet Plant Tour (2019)," accessed April 21, 2022.

Manufacturing wood pellets entails several steps. Raw material wood feedstock is harvested or collected and transported to wood pelletization plants. For the roundwood and tree part inputs, they are placed in a debarking machine and then cut into chips which are screened for quality and waste is removed. Next, the various inputs (chips and forestry residues) are broken down into a fine powdery substance, which is compressed and extruded from machines as wood pellets. The wood pellets are cooled, hardened, and packaged. Finally, the wood pellets are transported to a power plant or other destination for usage.[8]

**Figure 1** Wood pellets

Source: D-Kuru/Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Wood_pellets-small_huddle_PNr%C2%B00108.jpg.

To generate electricity or heat, wood pellets are burned in combustion devices,[9] such as boilers, burners, or stoves.[10] Before the late 2000s, wood pellets were mostly burned by individual offices and residences for heating. Increasingly, utilities are burning wood pellets to produce utility-scale electricity or combined heat and power (CHP) in industrial and commercial applications.[11] This paper focuses on electricity and CHP utility wood pellet consumption, as they are most relevant to international trade.

Although wood pellet consumption data is limited, there is no doubt that wood pellet consumption has increased significantly in recent years and that European countries are the main consumers. A European Pellet Council (EPC) report stated that global consumption of wood pellets reached 35 million tons in 2019; of this total, the EU (including the UK) consumed 26.1 metric tons which is about 75 percent of the global total.[12] A 2021 USDA report estimated that EU consumption of wood pellets has increased 115 percent between 2012 and 2021.[13] Although far behind, the EPC report estimated that Asia excluding China was the second largest consumer with 4.8 metric tons in 2019.[14]

[8] Drax, "This Is How You Make a Biomass Wood Pellet," October 6, 2016.
[9] During combustion, wood pellets emit several substances. See Box 1 for more information.
[10] Perez-Jimenez, "Biomass Pellet-Fired Boilers," 2015.
[11] Goetzl, "Developments in the Global Trade of Wood Pellets," January 2015, 1.
[12] EPC, "Wood Pellet Map," accessed April 19, 2022.
[13] USDA, "Biofuels Annual (European Union)," June 22, 2021.
[14] EPC, "Wood Pellet Map," accessed April 19, 2022. Although not specified in the report, South Korea and Japan were likely the predominant Asian consumers.

**Box 1** Wood Pellet Combustion Emissions

Wood pellets emit several substances when burned. These substances include carbon dioxide, nitrogen oxide, nitrous oxide, sulfur oxide, carbon monoxide, methane, carbon monoxide, total organic compounds, ozone, and particulate matters.[a] Some of these emissions, such as carbon dioxide and methane, are greenhouse gases.[b] Wood pellets share this emissions characteristic with firewood, a tree-derived solid biomass that has been used by humans as fuel for millennia,[c] and fossil fuels like coal. When burned, wood fuels such as wood pellets generally emit more carbon dioxide than fossil fuels per unit of energy produced.[d] Scholars have long pondered these and other complexities, nuances, and implications of biomass energy systems.[e] Wood pellet carbon emissions, whether wood pellets are a renewable or non-renewable energy, air quality, biodiversity, soil health, and other factors have contributed to environmental controversies over the accelerating global consumption of wood pellets.[f] For more analysis on wood pellet carbon emissions and the trade-environment nexus, see the appendix.

[a] Perez-Jimenez, "Gaseous Emissions from the Combustion of Biomass Pellets," 2015.
[b] Such emissions increase atmospheric greenhouse gas levels, which worsen climate change. For simplicity, this paper generally uses "carbon dioxide," "$CO_2$" or "carbon" rather than the broader term "greenhouse gases."
[c] Radkau, "Wood: A History," 2012, 18.
[d] European Commission, "Carbon Accounting of Forest Bioenergy," 2013, 16.
[e] See, for example, Marland and Schlamadinger, "Biomass Fuels and Forest-Management Strategies," 1995.
[f] Cornwall, "Is Wood a Green Source of Energy?," 2017.

# EU Support for Wood Pellet Energy

Wood pellet consumption in the EU[15] has grown robustly because of EU regulatory and financial support.[16] Partially based on a United Nations Framework Convention on Climate Change and Intergovernmental Panel on Climate Change biomass carbon accounting methodology, this has entailed, most notably, designating wood pellets as a renewable energy; counting wood pellet combustion carbon emissions as zero; and providing subsidies to consumers and producers of wood pellets.[17] Reportedly, the EU has provided such support and special carbon measurement calibrations because of the inordinate difficulty of otherwise attaining their climate decarbonization pledges.[18] The current limitations on installed generation capacity of the classic renewable energies of wind, solar, hydro, and geothermal—and the diminishment of low-carbon nuclear power, particularly in Germany—make this particularly challenging. Moreover, if the wood pellet related carbon emissions are considered to have occurred at combustion, the ensuing measurement would result in the EU being unable to meet its carbon emission threshold objectives. As Frans Timmerman, the European Commission's Vice Chair, said in November 2021 at the UN Climate Conference in Glasgow, Scotland, "to be perfectly blunt with you,

[15] In this context, the EU includes the United Kingdom, which was a member of the EU when the EU RED was adopted. Since the United Kingdom's departure from the EU in 2020, both the EU and United Kingdom continue to provide similar regulatory and financial support for wood pellet consumption.
[16] Brack, Birdsey, and Walker, "Greenhouse Gas Emissions from Burning US-Sourced Woody Biomass," October 2021, 24; Aguilar et al., "Expansion of US Wood Pellet Industry," December 2020.
[17] For more background on how the biomass climate carbon accounting construct emerged, see the appendix.
[18] European Commission, "Renewable Energy Progress Report," October 14, 2020, 3.

biomass will have to be part of our energy mix if we want to remove our dependency on fossil fuels. I do admit that it's quite complicated to get this right."[19]

# European Union Renewable Energy Directive

The fundamental and impactful instrument for the EU's biomass incentivization was the EU's Renewable Energy Directive (RED). The EU adopted the RED on April 23, 2009, as part of its Energy and Climate Change Package (CCP). The CCP included "20/20/20" mandatory goals for 2020, which consisted of a 20 percent binding target for renewable energy in the EU's overall energy mix, a 20 percent reduction in carbon dioxide emissions, a 20 percent increase in the EU's energy efficiency, and a 10 percent renewable energy blending target for the EU's transport sector. The allocated targets for each individual EU member state varied based on a range of factors, such as wealth and capacity.[20]

Biomass is considered a renewable energy under the EU's RED,[21] which means biomass consumption can contribute to attaining the EU's renewable energy targets. Because the EU also considers biomass to emit no carbon when burned, the carbon emissions from wood pellet combustion count as zero. These assumptions follow the EU precedent of considering biomass a renewable energy and carbon neutral.[22] For instance, under the EU Emission Trading System (EU ETS), a cap-and-trade carbon pricing system established in 2005, biomass carbon emissions are considered carbon neutral. Due to an initial oversupply of carbon emission allowances, the EU ETS carbon price was low for many years and probably had minor impacts on incentivizing increased consumption of energies the EU considered renewable. The RED provisions, however, as well as generous subsidies, strongly incentivized the rapid growth in EU wood pellet consumption.[23]

Some analysts have expressed concerns that increased biomass production could potentially contribute to deforestation and harm biodiversity.[24] Deterring these risks is frequently termed "sustainability requirements." Although biofuels and bioliquids[25] were subject to some sustainability requirements under the RED, solid biomass such as wood pellets were not.[26] For instance, the RED proscribed that biofuels and bioliquids cannot be made from land with "high carbon stocks" (e.g., wetlands) or "high biodiversity value" (e.g., "wooded land of native species").[27] Because of the omission of solid biomass sustainability requirements in the RED, several EU member states—including the major importers of Belgium, Denmark, and the Netherlands—adopted their own sustainability requirements for solid

[19] Birnbaum, "E.U.'s Big Climate Ambitions," November 10, 2021.
[20] Howes, "The EU's New Renewable Energy Directive," 2010.
[21] EU Renewable Energy Directive, Article 2(a), April 23, 2009.
[22] Matthews, "Assessment of EU LULUCF Regulation," December 21, 2020, 6; Goetzl, "Developments in the Global Trade of Wood Pellets," January 2015, 11.
[23] Brack, Birdsey, and Walker, "Greenhouse Gas Emissions from Burning US-Sourced Woody Biomass," October 2021, 24; Trinomics, "Financial Support for Electricity Generation and CHP," November 19, 2019.
[24] Brack, "Woody Biomass for Power and Heat," February 2017, 8; Matthews, "Assessment of EU LULUCF Regulation," December 21, 2020, 14–15.
[25] Biofuels and bioliquids are liquid fuels derived from biomass and thus differ from wood pellets which are a solid biomass energy.
[26] European Commission, "The Use of Woody Biomass," 2021, 78.
[27] EU Renewable Energy Directive, Article 17, April 23, 2009.

biomass.[28] The EU eventually added standardized biofuel sustainability requirements in 2021 that included biomass under the EU RED II.[29]

# EU Subsidies

Government subsidies for energy products, such as fossil fuels, are common.[30] Such subsidies are primarily intended to reduce energy costs for consumers. The overriding goal for renewable energy subsidies is somewhat different, namely decarbonization, by becoming more competitive with fossil fuels and leading to a larger share of the overall energy mix. Similarly—whether biomass is a renewable energy or not—EU member states, the United Kingdom, and others have provided subsidies to consumers and producers of biomass to increase consumption of this energy product to support their climate change policies.

A 2021 report, partially funded by the European Union, estimated that biomass subsidies for 14 EU countries increased from €4.5 billion in 2015 to €5.3 billion in 2017.[31] Befitting its large economy and population, Germany was the largest subsidizer at €1.9 billion. The totals for the main EU member state importers of U.S. wood pellets were Belgium (€338 million in 2017), Denmark (€104 million in 2019), and the Netherlands (€242 million in 2019). A previous report by the same authors stated that the United Kingdom provided €1.6 billion in wood pellet subsidies in 2017.[32] Although infeasible to precisely measure the impact of these biomass subsidies, it likely contributed to the increases in EU and UK biomass consumption.[33]

**Box 2** Energy Product Subsidy Categories

The European Commission, in a 2021 report, divided energy product subsidies into four categories:

- *Direct transfers* - direct payments to consumers or producers in the form of grants or preferential loans.
- *Tax expenditures* - tax reductions, tax exemptions, tax refunds, tax credits, and tax allowances.
- *Income or price supports* - financial mechanisms that provide advantages to the recipients on matters such as prices. Feed-in tariffs and price guarantees are examples.
- *Research, Development, and Demonstration (RD&D) budgets* - financial or other preferential mechanisms to support research and development.[a]

[a] European Commission, "Study on Energy Subsidies," July 2021, 13.

[28] USDA, "Biofuels Annual (European Union)," June 22, 2021, 7.
[29] See the "EU State of Play" section later in this paper.
[30] Parry, Black, and Vernon, "Still Not Getting Energy Prices Right," 2021. See Box 2 for a categorization of energy product subsidies.
[31] Trinomics, "Analysis on Biomass," March 2, 2021, 12.
[32] Trinomics, "Financial Support for Electricity Generation and CHP," November 19, 2019, 24.
[33] Trinomics, "Financial Support for Electricity Generation and CHP," November 19, 2019.

# Wood Pellet International Trade

Wood pellet trade analysis is aided by the existence of a specific Harmonized Tariff Schedule (HTS) subheading since 2012 for wood pellets, HTS subheading 4401.31. Before 2012, wood pellets were in a broader HTS subheading, 4401.30, which included wood pellets, sawdust, fire logs, and similar products. Like all goods that are traded, however, wood pellets are still subject to trade measurement challenges, as discussed in Box 3. Nonetheless, several dynamics are clear about international trade in wood pellets. Most prominently, international trade in wood pellets has grown substantially after the EU adopted the RED in 2009. Second, international trade is a fundamental dynamic in the recent growth in the wood pellet industry, particularly for purposes of industrial energy consumption.[34] Third, wood pellet exports and imports are concentrated in a few countries. Fourth, because many[35] of the largest industrial consumers of wood pellets do not have significant timber resources, they do not have the capacity to be self-sufficient producers.[36] Accordingly, such countries must import wood pellets from countries that do.

**Box 3** Wood Pellet Trade Data Challenges

Trade data is subject to measurement accuracy challenges.[a] In global trade databases, the trade in wood pellets, especially related to the EU, "re-exports" can be mistermed as "exports." Denmark is a prime example of this. A significant consumer and importer of wood pellets, Denmark is also reported in trade databases as being a large exporter even though—being a country with minimal forests—it does not produce wood pellets. This is because Denmark is a transshipment point for wood pellets on their way to other parts of the EU. More accurate estimates can potentially be obtained by analyzing Danish consumption of wood pellets and using mirror statistics.[b]

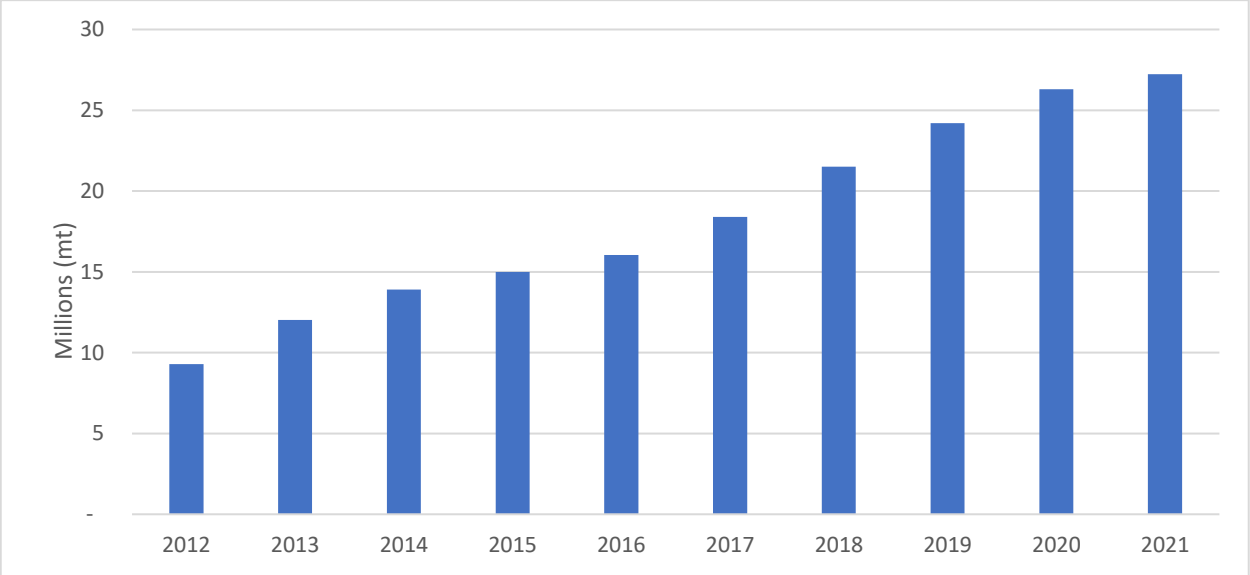
[a] See, for example, Yasui, "The Unreliability of Merchandise Trade Statistics," 2018.
[b] USDA, "Biofuels Annual (European Union)," June 29, 2020, 51.

# Global Wood Pellet Exports and Imports

Although still a small amount of the international trade in energy products, wood pellet exports and imports have steadily increased since the late 2000s. By quantity, global wood pellet exports increased 192.2 percent from 9.4 million metric tons in 2012 to 27.3 million metric tons in 2021 (figure 2). By value, global wood pellet exports increased 165.2 percent, from $1.6 billion to $4.3 billion.[37]

[34] Austria, Croatia, Czechia, France, Germany, Spain, and Sweden are large residential consumers of wood pellets, but are not large industrial consumers. In addition, these countries are not large importers of wood pellets as they have significant domestic production. USDA, "Biofuels Annual (European Union)," June 22, 2021, 38.
[35] An exception is Germany, which is both a large producer, exporter, and consumer of wood pellets.
[36] These countries include Belgium, Denmark, Japan, the Netherlands, the United Kingdom, and South Korea. Italy is also a large importer of wood pellets, but it is more of a residential consumer than industrial consumer. USDA, "Biofuels Annual (European Union)," June 22, 2021, 38–39.
[37] IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed March 3, 2022.

**Figure 2** Global wood pellet exports, quantity




Source: IHS Markit, Global Trade Atlas database, Quantity (metric tons), HTS subheading 4401.31, 2012-2020, accessed April 19, 2022.

The United States is the largest global wood pellet exporter, accounting for more than 27 percent of total exports by quantity in 2021 and nearly 25 percent by value.[38] After the United States, the largest exporters in 2021 by quantity were Vietnam,[39] Canada, Latvia, Russia, and Estonia. Table 1 reflects the top exporters and their primary destination.

**Table 1** Top wood pellet exporters, 2021, quantity

| Largest exporters | Total exports | Top destination | Top destination share |
|---|---|---|---|
| **United States** | 7.5 million mt | United Kingdom | 71.9% |
| **Vietnam** | ≈3.7 million mt | South Korea | 62.6% |
| **Canada** | 3.1 million mt | United Kingdom | 40.0% |
| **Latvia** | 2.5 million mt | United Kingdom | 55.9% |
| **Russia** | 2.4 million mt | Denmark | 39.5% |
| **Estonia** | 1.5 million mt | Denmark | 58.6% |

Source: IHS Markit, Global Trade Atlas database, accessed April 19, 2022.

The United Kingdom was the largest importer in 2021, accounting for nearly 32 percent of total imports by quantity and 34.6 percent by value.[40] After the United Kingdom, the largest importers by quantity in 2020 were South Korea, Denmark, Japan, Netherlands, and Italy. Table 2 reflects the top importers and their primary supplier.

[38] IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed March 7, 2022.
[39] Vietnam does not report trade data to IHS Markit. The total was calculated by adding South Korean and Japanese wood pellet imports from Vietnam.
[40] IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed March 23, 2022.

**Table 2** Top wood pellet importers, 2021, quantity

| Largest importers | Total imports | Top supplier | Top supplier share |
|---|---|---|---|
| **United Kingdom** | 9.1 million mt | United States | 59.2% |
| **South Korea** | 3.4 million mt | Vietnam | 62.6% |
| **Denmark** | 3.2 million mt | Latvia | 24.9% |
| **Japan** | 3.1 million mt | Vietnam | 52.8% |
| **Netherlands** | 2.8 million mt | United States | 42.5% |
| **Italy** | 1.9 million mt | Austria | 31.5% |

Source: IHS Markit, Global Trade Atlas database, accessed April 19, 2022.

# U.S. Wood Pellet Production and Exports

Most U.S. produced wood pellets are for export and not domestic consumption. The U.S. Energy Information Agency (U.S. EIA) reported that in November 2021, 77.2 percent of U.S. produced wood pellets were exported and 22.8 percent were consumed domestically.[41] Wood pellets are produced in every region of the United States and in at least 34 states.[42] A majority of U.S. wood pellets, particularly utility pellets intended for export, are produced in the U.S. South. Accordingly, this paper focuses on producers in the U.S. South because they account for most exports. The predominance of the U.S. South as a producer and exporter of utility pellets is likely due to, among other reasons, that region's sizeable timber plantations, history of wood producing industries, existing infrastructure, limited forest protections, relatively low wages, and the relative proximity of U.S. Southern ports to Europe.[43] The U.S. Pacific Northwest, despite containing large timber resources and being closer than the U.S. South to the growing markets of South Korea and Japan, is not currently a major producer or exporter of wood pellets.

## Wood Harvesting in the U.S. South

The U.S. South, with its sizable forests and timber plantations, has long been a lucrative region for wood-input industries. Beginning in the 1860s during Reconstruction, and with the objective of supporting development in the economically distressed region, the U.S. government sold off massive amounts of public lands in the U.S. South to private interests. The lumber industry was a big buyer, securing ownership of hundreds of millions of acres which especially contained pines and cypresses. Benefiting from the abundant natural resources, low labor wages, and no restrictions on clearcutting, the lumber industry acquisitions in the South rapidly became extremely profitable. By the time restrictions were placed on the sale of public land sales in 1889, much of the forested areas were in private hands and being clear-cut.[44]

In the 1930s, with much of the U.S. South deforested, pulp and paper companies moved in to embark on monocultural regeneration and harvesting of fast-growing pines. The region quickly became the dominant U.S. region for the pulp and paper industry. By the 1990s, the U.S. South reportedly had about three-fourths of domestic pulpwood production and half of the country's paper and paperboard

[41] U.S. EIA, "Monthly Densified Biomass Fuel Report," accessed February 16, 2022.
[42] Biomass Magazine, "U.S. Pellet Plants," December 14, 2021.
[43] Boyd, "The Slain Wood," 2015; Singh et al., "Locational Determinants for Wood Pellet Plants," 2016; Young et al., "Logistic Regression Models of Factors Influencing the Location of Bioenergy and Biofuels Plants," 2011.
[44] Boyd, "The Slain Wood," 2015, 1–3.

production. To this day, papermaking and lumber production are mainstays of the U.S. South.[45] In the 2000s, a wood-input industry newcomer—the emergent wood pellet industry—entered the conducive regional market to meet the emerging demand from Europe.

Biomass Magazine reported that as of December 2021 there were 117 operational wood pellet plants in the United States with a total capacity of 14,388 metric tons per year.[46] Of the 28 wood pellet plants with capacity of more than 100 metric tons per year, 21 are based in the U.S. South. The largest U.S. wood pellet producer, Enviva, is headquartered in Bethesda, Maryland, and has wood pellet plants in six southern states: Florida, Georgia, Mississippi, North Carolina, South Carolina, and Virginia.[47] Drax Group (Drax), a British utility that is incrementally shifting from coal burning to wood pellet burning at its electricity generating power plants, owns or has interests in 17 pellet mills in the U.S. South and Western Canada, and exports the product from the United States and Canada to the United Kingdom.[48]

# Wood Pellet Export Shipments from Ports in the U.S. South

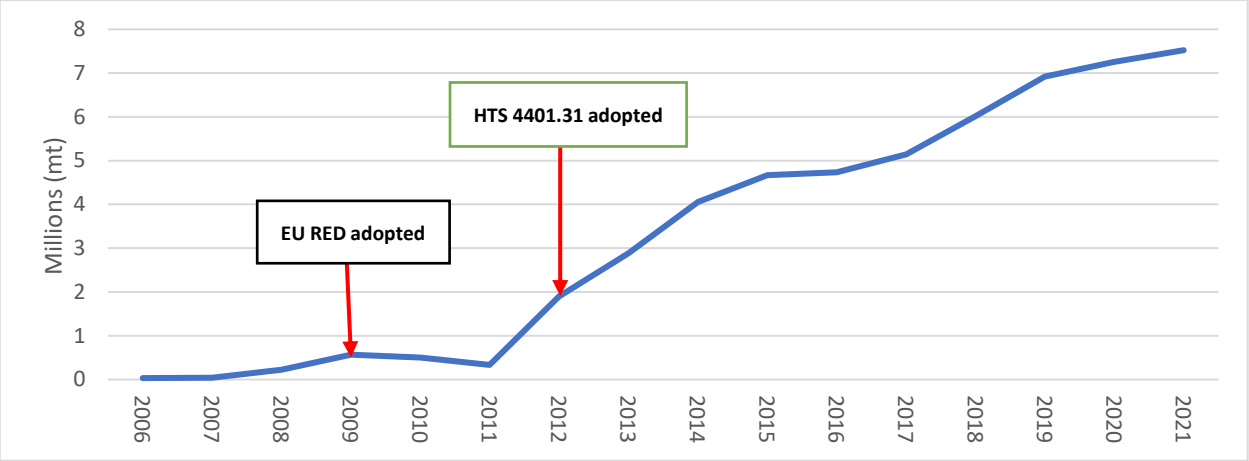
The bulk of U.S. wood pellet exports are currently shipped from ports in the U.S. South across the Atlantic Ocean in container ships to Europe. This is most likely because of the convenience provided by the relative efficiency and relatively low cost of ocean shipments from U.S. southern ports to European utility facilities. Enviva and Drax ship from several ports in the U.S. South. Enviva reports that they ship wood pellets from six southern ports: Port of Chesapeake, Virginia; Port of Mobile, Alabama; Port of Panama City, Florida; Port of Pascagoula, Mississippi; Port of Savannah, Georgia; and Port of Wilmington, North Carolina.[49] Enviva owns the Port of Chesapeake and the Port of Pascagoula. Drax ships wood pellets from its facility at the Port of Mobile, Alabama to its power plants in the United Kingdom.[50] Trade data by value reflects that over 97 percent of U.S. wood pellet exports were shipped from southern port districts in 2021.[51]

# U.S. Wood Pellet Exports

U.S. exports of wood pellets were relatively small until several years after the EU adopted the RED in 2009 (figure 3). Beginning in 2012, the U.S. wood pellet export business took off. Between 2012 and 2021, U.S. wood pellet domestic exports increased 296.3 percent by quantity (figure 4) and 310.1 percent by value (figure 5). U.S. wood pellet exports became a $1 billion business for the first time in 2021 (figure 5).

[45] Boyd, "The Slain Wood," 2015, 6–17.
[46] Biomass Magazine, "U.S. Pellet Plants," December 14, 2021.
[47] Enviva, "Our Plants," accessed February 16, 2022.
[48] Drax, "Construction Starts," September 17, 2021; Drax, "Drax Completes Acquisition of Pinnacle Renewable Energy," April 21, 2021.
[49] Enviva, "Our Ports," accessed February 22, 2022; Southern Environmental Law Center, "Southeast U.S. Wood Pellet Plants," July 21, 2021.
[50] Drax, "Drax Receives 100th Biomass Cargo," April 6, 2020; Southern Environmental Law Center, "Southeast U.S. Wood Pellet Plants," July 21, 2021.
[51] USITC DataWeb/Census, HTS subheading 4401.31, accessed February 22, 2022.

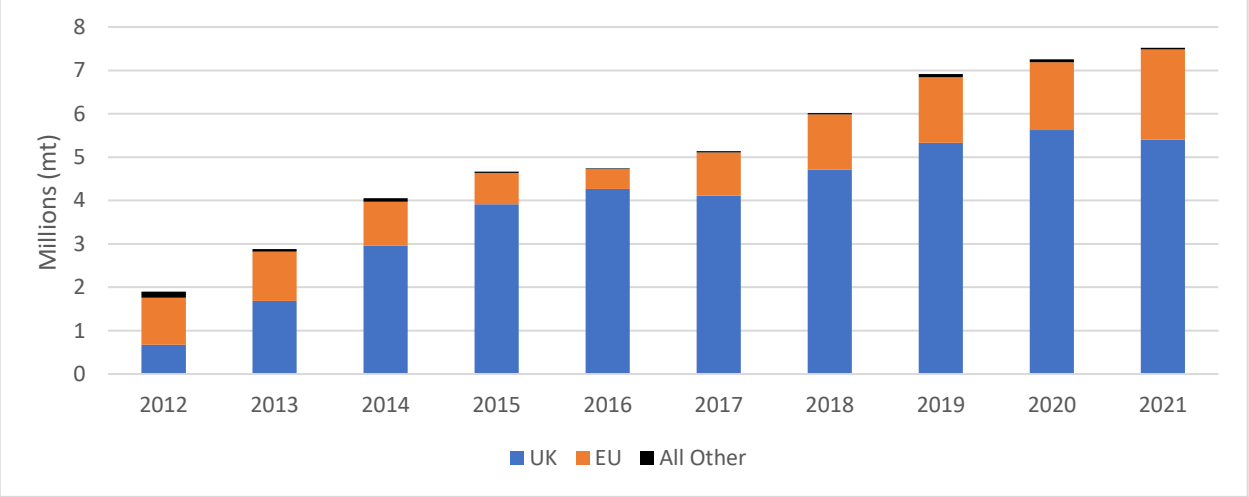
**Figure 3** U.S. wood pellets, sawdust, fire logs, and similar products exports (2006–11) and U.S. wood pellet exports (2012–21), quantity




Sources: Adapted from Eastin, "Opportunities for US Wood Pellets," 2019; USITC DataWeb/Census, HTS subheading 4401.30 (2006–11) and HTS subheading 4401.31, (2012–21), accessed February 8, 2022.
Note: 4401.31 is the wood pellet specific code.

The United States exports most of its wood pellets to the United Kingdom, and secondarily to the EU (figure 4). Between 2012 and 2021, U.S. wood pellet domestic exports to the United Kingdom increased by 703.1 percent by quantity and 563.0 percent by value.[52] Aside from the United Kingdom, the EU is the largest destination for U.S. wood pellet exports (especially the Netherlands, Denmark, and Belgium) with a sliver going to countries outside the United Kingdom and EU. In 2021, 71.9 percent of U.S. wood pellet exports by quantity went to the United Kingdom, 27.6 percent went to the EU, and 0.5 percent went to all other countries.

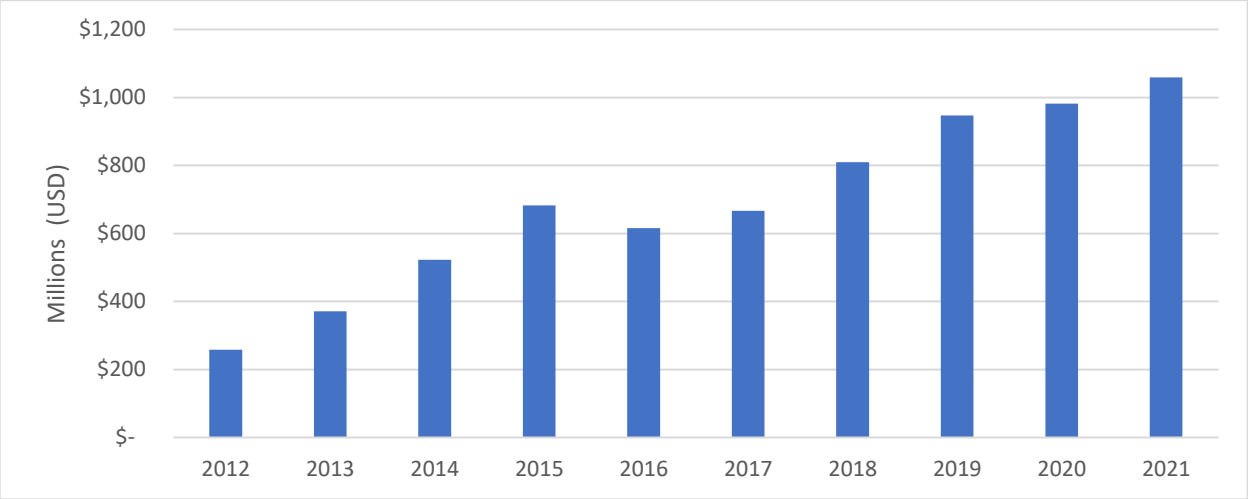
**Figure 4** U.S. wood pellet exports, destinations, quantity




Source: USITC DataWeb/Census, U.S. domestic exports, HTS subheading 4401.31, accessed February 15, 2022. Note: Exports to Guadeloupe and Martinique are considered exports to the EU (France).

[52] USITC DataWeb/Census, HTS subheading 4401.31, accessed February 15, 2022.

**Figure 5** U.S. wood pellet exports, value




Source: USITC DataWeb/Census, U.S. domestic exports, HTS subheading 4401.31, accessed February 15, 2022.

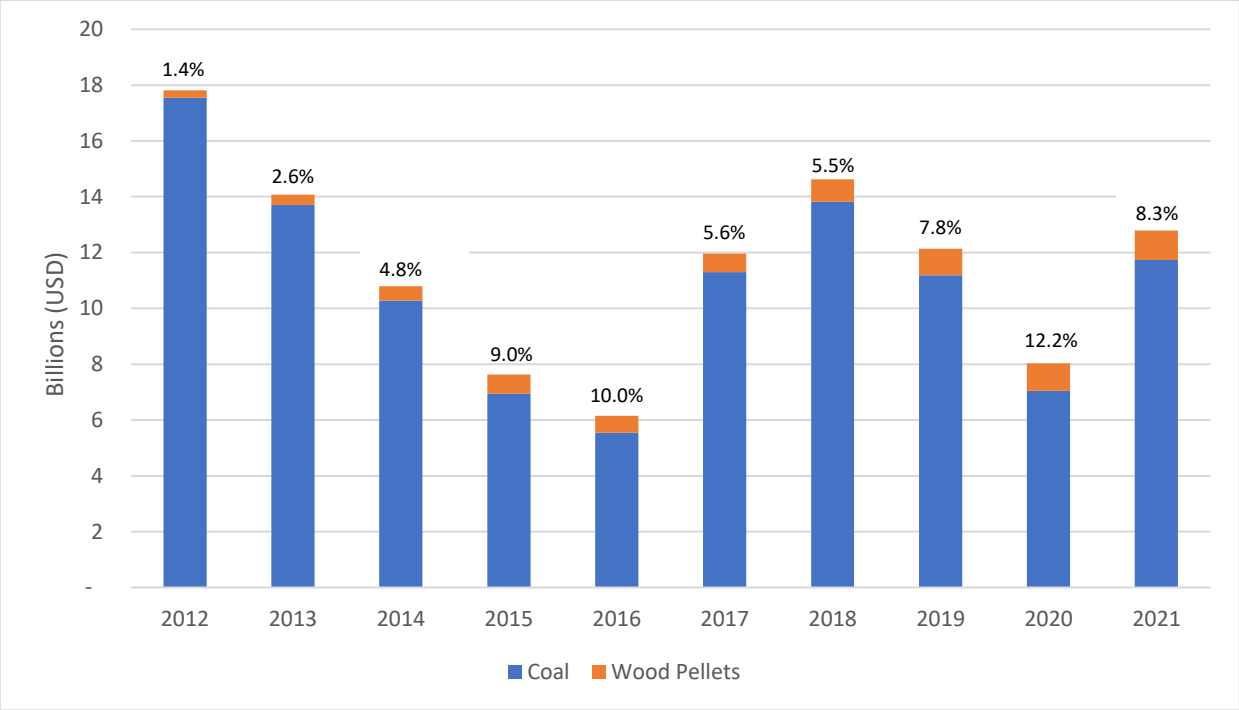
# U.S. Coal Exports and U.S. Wood Pellet Exports

Wood pellets are co-firing with or replacing coal in some power plants, especially in the United Kingdom. Thus, wood pellets can be viewed as a substitute for coal. Despite the significant increase in U.S. wood pellet production and exports, however, it is important to note that U.S. coal exports (by far the smallest of U.S. fossil fuel sector exports) are still much larger. U.S. exports of coal, coke, and related chemical products ($11.7 billion) were more than 10 times larger than U.S. exports of wood pellets ($1.1 billion) in 2021. Thus, although the value of U.S. exports of wood pellets by percentage has increased considerably more than U.S. exports of coal between 2012 and 2021—U.S. wood exports have increased by 310.1 percent while U.S. coal exports have decreased by 33.2 percent—U.S. coal exports remain much larger and will be so for the foreseeable future (figure 6).[53]

The largest destinations for U.S. coal in 2021 were China, India, Brazil, Canada, the Netherlands, Japan, South Korea, and Ukraine.[54] Three of the top destinations for U.S. coal exports (the Netherlands, Japan, and South Korea) were also large importers of wood pellets, although only one (the Netherlands) imports a substantial amount of wood pellets from the United States.

[53] USITC DataWeb/Census, HTS subheading 4401.31 and USITC EP003 digest, accessed February 22, 2022.
[54] USITC DataWeb/Census, USITC EP003 digest, accessed February 22, 2022.

**Figure 6** U.S. coal and wood pellet exports, value. Percentages above the bars are the ratio of wood pellet exports to the total of coal and wood pellet exports




Source: USITC DataWeb/Census, HTS subheading 4401.31 and USITC EP003 digest, accessed February 15, 2022.

# Wood Pellet Growth Markets

Although the United Kingdom and the EU have been the leading wood pellet consumers and importers, South Korea and Japan are also quickly becoming significant markets. The increased consumption in both countries is also driven by their climate change policies. South Korea and Japan obtain most of their wood pellets from several Asian countries and Canada. To date, the United States has only exported a tiny amount of wood pellets to Asia, likely because most U.S. wood pellets are produced in the U.S. South rather than the Western U.S. An industry observer has suggested, however, that this could change.[55] Factors and recent events that could support this theory are that South Korea and Japan are rapidly increasing their use of wood pellets; the U.S. Pacific Northwest has sizeable forests; Western Canada (British Columbia) has already demonstrated the feasibility of exporting significant wood pellet volumes to South Korea and Japan; and Enviva has contracted with Japan to export substantial amounts of U.S. wood pellets in the future.

## South Korea

South Korea's increased focus on wood pellets emanates from its climate change policies. In 2012, South Korea adopted a Renewable Portfolio Standard (RPS) which required power companies with installed capacity of over 500 megawatts (MW) to generate at least a minimum percentage of gross power generation from renewable energy sources. In South Korea's original RPS legislation, the renewable

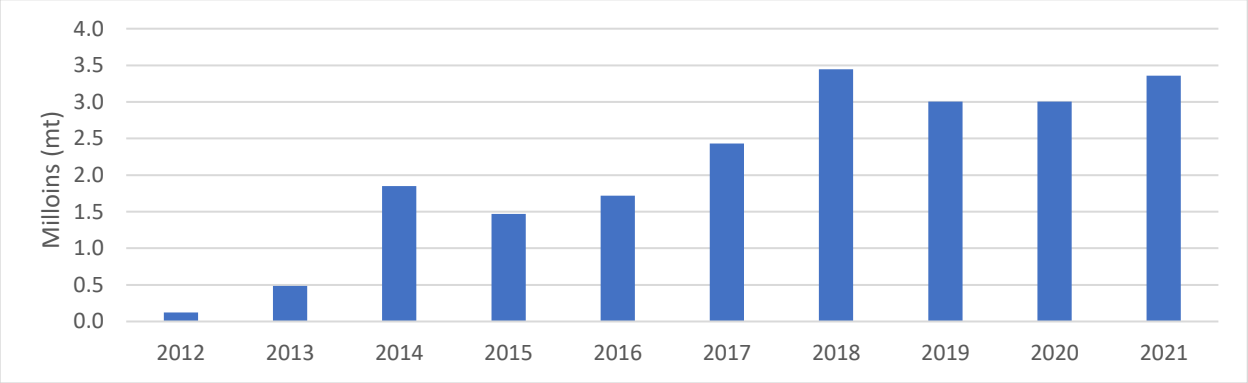
[55] Eastin, "Opportunities for US Wood Pellets," 2019.

energy share was set at 2 percent at the 2012 launch and scheduled to incrementally increase to 10.0 percent in 2022. Under recent legislation, the government set the share to 25 percent by 2026.[56] Like in the EU, biomass is considered a renewable energy under South Korea's RPS, which has contributed to its growth.

The South Korea RPS functions as a cap-and-trade system with power companies being issued Renewable Energy Certificates (RECs) for the renewable energy they produce. For power companies that do not reach the required renewable energy threshold, they can purchase RECs from other power companies to comply with the law or pay fines. The number of RECs earned per megawatt-hour (weightings) are determined by the type of technology used and other factors. The REC weightings have been adjusted frequently. Korean biomass consumers and producers thus earn RECs which they can in turn sell to power producers who need them.[57] Under recent legislation, the South Korean government is attempting to reduce the proportion of wood pellets that are imported—reportedly approximately 90 percent—to support the domestic wood pellet industry.[58]

South Korea's wood pellet imports increased by a factor of 27 from 2012 to 2021 to total 3.4 million metric tons (figure 7). South Korea is now the second largest importer of wood pellets globally; in 2012 it was the tenth largest importer. The largest suppliers of South Korea's wood pellet imports in 2021 were Vietnam (62.6 percent), Malaysia (12.1 percent), and Canada (9.8 percent). South Korea imported a miniscule amount from the United States (45 thousand metric tons) in 2021.

**Figure 7** South Korea wood pellet imports, quantity




Source: IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed February 15, 2022.

# Japan

Japan has limited natural resources and must import most of its fuel. Although nuclear power once provided a substantial amount of Japan's energy needs, this changed in the aftermath of the 2011 Tōhoku earthquake and tsunami, and the subsequent accident at the Fukushima Daiichi nuclear power

[56] Seol et al., "The Renewable Energy Law: South Korea," August 10, 2021.
[57] Seol et al., "The Renewable Energy Law: South Korea," August 10, 2021; Levinson, "Wood Pellets in the Emerging Asian Biomass Market," May 23, 2018.
[58] Chang-Won, "S. Korean Companies," September 1, 2021.

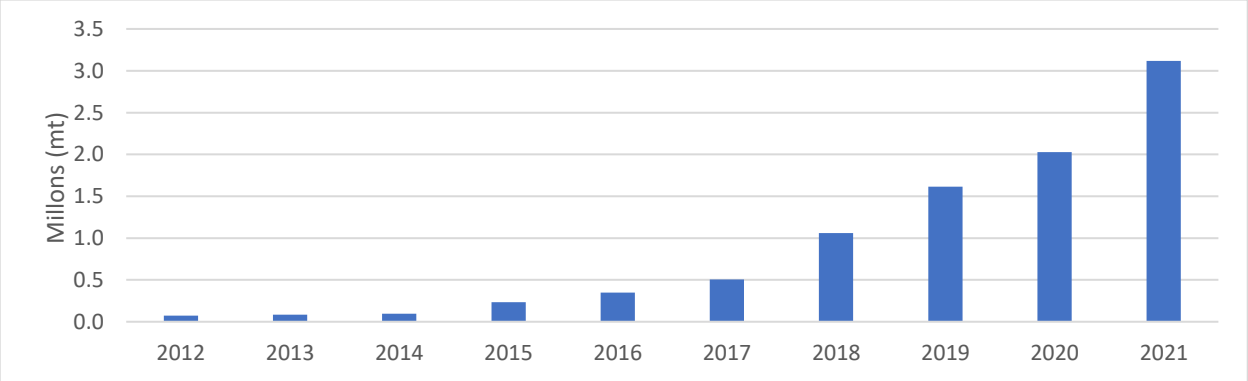
plant. Following the disaster, Japan substantially reduced its energy share drawn from nuclear, although it has recently been gradually increasing again.[59]

Japan has also attempted to increase its use of renewable energy consumption to comply with its climate change pledges. Accordingly, Japan established a Feed-In Tariff Scheme (FiT) in 2012, where the total volume of electricity[60] generated by renewable energy is purchased at a fixed price for a fixed term. Under Japan's FiT, biomass is considered a renewable energy.[61] Utilities can charge customers a premium (tariff) for electricity generated by biomass compared to fossil fuels. Although the tariffs are less generous for imported wood pellets, the Japanese domestic wood industry is too small to meet the country's growing demand. Japan is continuing to ramp up its consumption of biomass and in its 6th Strategic Energy Plan (SEP), it announced plans to double by 2030 the amount of biomass used in 2019.[62]

Because of these developments and dynamics, there has been a quickening of Japan's wood pellet imports (figure 8). Between 2012 and 2021, Japan's wood pellet imports increased by a factor of 43 to 3.1 million metric tons.[63] In 2021, Japan was the sixth largest importer of wood pellets globally; in 2012 it was the twelfth largest importer. The largest suppliers of Japan's wood pellet imports in 2021 were Vietnam (52.8 percent) and Canada (34.0 percent).[64]

Like South Korea, Japan imported a tiny amount from the United States (27 thousand metric tons) in 2021, but this is expected to increase. Enviva announced in December 2020 its first wood pellet export to Japan, a shipment of 28 thousand metric tons from Port Panama City, Florida to Japan's Iwakuni Port.[65] Reportedly, by 2025, 50 percent of Enviva's wood pellet off-take contract mix—more than 3 million metric tons—will go to Japanese customers.[66]

**Figure 8** Japan, wood pellet imports, quantity




Source: IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed February 15, 2022.

[59] USDA, "Biofuels Annual (Japan)," December 21, 2021, 5.
[60] Japan's FiT applies to electricity, not heating or transportation.
[61] Takeuchi and Higuchi, "The Renewable Energy Law Review: Japan," August 10, 2021.
[62] USDA, "Biofuels Annual (Japan)," December 21, 2021, 8.
[63] IHS Markit, Global Trade Atlas database, HTS subheading 4401.31, accessed February 4, 2022.
[64] USDA, "Biofuels Annual (Japan)," December 21, 2021, 5.
[65] Enviva, "Enviva Commemorates First Shipment of Sustainable Biomass to Japan," December 2, 2020.
[66] Enviva, "Business Overview," August 17, 2021, 18.

# EU State of Play

The EU produced a successor to the RED—the Renewable Energy Directive II (RED II)—in December 2018.[67] The EU RED II increased the mandated share of energy from renewable sources in the EU's gross final consumption of energy to at least 32 percent by 2030.[68] The EU maintained biomass's designation as a renewable energy and thus biomass can contribute to the new 32 percent renewable energy requirement. In consideration of worries concerning potential environmental harm caused by biomass, the RED II includes text that biomass would join biofuels and bioliquids as being subject to some sustainability criteria. For instance, the RED II states that biomass should "not be made from raw material obtained from land with a high biodiversity value" and "land with high-carbon stock."[69] There remains the possibility that amendments could be made to the new biomass rules.[70]

In its most recent "Renewable Energy Progress Report," published in 2020, the European Commission reported that EU bioenergy consumption continued to be a significant and growing part of the EU's RED objectives. If bioenergy is considered a renewable energy, the EU27 (the EU without the UK) reached a share of 18.9 percent of renewable energy in gross final energy consumption in 2018,[71] which put it on track to meet its 2020 objective of 20.6 percent.[72] If bioenergy is not considered a renewable energy, the EU27's renewable energy share in 2018 would have been 7.56 percent,[73] which is substantially under the 2020 goal of 20 percent. This was estimated as, under the EU's assumptions used for this measurement, roughly 60 percent of the renewable energy[74] consumed in the EU was generated by bioenergy, of which 68.4 percent was solid biomass.[75] Of the biomass total, approximately 91 percent was forestry related.[76] Accordingly, about 7.05 percent of the EU's gross final energy consumption in 2018 was from forestry related biomass (which is predominantly wood pellets).[77]

A broader and earlier report by the International Energy Agency (IEA) had similar but not identical share breakdowns: it stated that in 2017, EU Total Primary Energy Supply shares were oil (33 percent), natural gas (25 percent), coal (14 percent), nuclear (13 percent), bioenergy and waste (10 percent), and classic

[67] The EU also adopted, in 2018, a regulation on land use, land use change, and forestry (LULUCF Regulation) which mandated that carbon dioxide emissions from domestic land use are balanced by at least an equivalent accounted removal of carbon dioxide from the atmosphere in the period 2021 to 2030. Because the LULUCF Regulation only covers land use within the EU, it will not directly impact the international trade in wood pellets. Brack, Birdsey, and Walker, "Greenhouse Gas Emissions from Burning US-Sourced Woody Biomass," October 2021, 21; Matthews, "Assessment of EU LULUCF Regulation," December 21, 2020, 32.
[68] EU Renewable Energy Directive II, December 21, 2018, paragraph 128.
[69] EU Renewable Energy Directive II, December 21, 2018, Article 29, paragraphs 3 and 4.
[70] Hodgson, "Biomass Industry Lobbies to Weaken Proposed EU Woodland Protection," April 12, 2022; Parshley, "Europe Rethinks Its Reliance on Burning Wood for Electricity," May 17, 2022.
[71] European Commission, "Renewable Energy Progress Report," October 14, 2020, 3.
[72] With the departure of the United Kingdom from the EU, the overall EU objective rose from 20 percent to 20.6 percent, as it is based on a weighting of existing EU member state objectives.
[73] Author calculations: 60% of 18.9 = 11.34; 18.9 – 11.34 = 7.56%.
[74] Although the report estimated bioenergy's share of EU 'renewable energy,' it did not do so for the classic renewables of wind, solar, hydro, and geothermal.
[75] European Commission, "Renewable Energy Progress Report," October 14, 2020, 3.
[76] European Commission, "Renewable Energy Progress Report," October 14, 2020, 3.
[77] Author calculations: 60% of 18.9 = 11.34; 68.4% of 11.34 = 7.75; 91% of 7.75 = 7.05%.

renewables (5 percent).[78] More broadly, the reported breakdown for 2017 was fossil fuels (72 percent), nuclear (13 percent), bioenergy and waste (10 percent), and classic renewables (5 percent).

# Conclusion

Wood pellet production, consumption, and trade have increased considerably in recent years because several governments have incentivized and incorporated biomass as an integral energy product in their climate change strategies. Most notably, this has entailed a rapidly growing supply chain of U.S. roundwood, tree parts, and tree residues transformed into wood pellets and exported to the United Kingdom and the EU. More recently, a new trend has emerged of increased wood pellet imports by South Korea and Japan from a broader mix of countries. Although small thus far, there are indications that the United States will soon join the group of major wood pellet exporters to South Korea and Japan. Most likely, the upward trend of wood pellet production, consumption, and trade—especially the supply chain to South Korea and Japan—will continue for the foreseeable future unless the governments of the active wood pellet exporting and importing countries meaningfully alter their environmental strategies and policies.

[78] IEA, "European Union 2020 – Energy Policy Review," June 2020, 26.

# Appendix A: Wood Pellets, Trade, and Environment

Environmental factors and perceptions are at the core of the rapid and recent growth in consumption, production, and trade in wood pellets, and the global conversation about the merits of this development. The contentions that biomass is a renewable energy and does not augment atmospheric carbon dioxide levels—even though it generally emits more carbon dioxide than fossil fuels during combustion—are key drivers. These contentions are partially based on the observation that harvested trees can potentially be replaced with new carbon sequestering trees, unlike fossil fuels which cannot be regrown. In other words, biomass is purportedly part of a cycle, where atmospheric carbon is absorbed by trees, then returned to the atmosphere when the trees are harvested and consumed, then absorbed again by new trees, and so on. The EU biomass measurement calibrations drew from prior international negotiations that arbitrarily opted to allocate carbon emissions to land use rather than biomass combustion. Moreover, although experts generally agree that energy product emissions cannot be measured at one specific point in time, they disagree on the scheduling parameters. There are also clashes on whether—and the extent—of harm to biodiversity and soil health caused by wood harvesting and monoculture replanting. Finally, the questionable hope that carbon can be captured and stored during biomass combustion is tenuous. This appendix delves into these wood pellet trade-environment nexus matters.

## Of Land Use or Combustion

Two options for quantitatively estimating biomass engendered carbon emissions are (1) estimating changes in a land area's carbon stock[79] due to harvesting[80] or (2) estimating stack carbon emissions from combustion.[81] The United Nations Framework Convention on Climate Change (UNFCCC), in its 1997 Kyoto Protocol, adopted a principal[82] that "sources and removals by sinks in the agricultural soils and the land-use change and forestry categories" should be considered when measuring "changes in greenhouse gas emissions."[83] In addition, the UNFCCC mandated the development of a methodology for this purpose.[84] Subsequently, the Intergovernmental Panel on Climate Change (IPCC) developed a methodology where, as one paper put it, "$CO_2$ emissions from use of bioenergy are counted in the land

[79] 'Carbon Stock' has been defined as "the amount of carbon that has been sequestered from the atmosphere and is now stored within the forest ecosystem, mainly within living biomass and soil, and to a lesser extent also in dead wood and litter." Forest Research, "Forest Carbon Stock," accessed March 23, 2022.
[80] Carbon dioxide is not released into the atmosphere during tree harvesting; carbon dioxide is released into the atmosphere during wood combustion or decay.
[81] A more obscure option, 'value chain approaches,' will not be discussed in this paper. See Pena, Bird, and Zanchi, "Improved Methods for Carbon Accounting for Bioenergy," 2011, 6–7.
[82] The concept predates the UNFCCC Kyoto Protocol: without naming the specific source for the contention, a 1991 OECD report stated it "has been argued that CO2 emissions resulting from bioenergy consumption should not be included in a country's official emission inventory." OECD, "Estimation of Greenhouse Gas Emissions and Sinks," 1991, 2–45.
[83] UNFCCC Kyoto Protocol, 1997, Article 3.4.
[84] Krug, "Accounting of GHG Emissions and Removals from Forest Management," December 2018, 2.

use sector as carbon stock losses, rather than as emissions in the energy sector, where emissions from fossil fuels are counted."[85] As they are ultimately, in theory, equivalent and duplicative, choosing one of these two options was intended to avoid double counting the carbon emissions.[86]

The UNFCCC and IPCC carbon accounting methodology did not have much of an impact initially as the volume of biomass consumption for energy purposes—and their carbon emissions—were inconsequential. Moreover, the U.S.-EU wood pellet trade was just emerging. In the coming years, however, especially following the adoption of the EU RED, the chosen methodology would have a significant impact.

The UNFCCC carbon accounting methodology enabled the EU and wood pellet businesses like Drax and Enviva to contend that burning wood pellets does not cause carbon emissions. For instance, under the UNFCCC (and EU) methodology and in the context of U.S.-EU wood pellet trade, the carbon emissions are ostensibly allocated to the United States (the producer and exporter) and not the EU (the importer and consumer). This insinuates that the United States generated the carbon emissions by harvesting wood for manufacturing wood pellets for their ultimate purpose, namely energy, and does not insinuate that the EU generated carbon emissions by burning the wood pellets.

UNFCCC parties are obligated to self-report their national carbon emissions in the UNFCCC's National Inventory Report (NIR). Carbon emissions from the combustion of wood pellets are not recorded In the NIR of the country where the combustion takes place. For instance, the United Kingdom stated in its 2021 NIR that the "$CO_2$ emissions from biomass are, however, not added to the total UK emissions from fuel combustion."[87] Theoretically, the carbon emissions from the burning of wood pellets in the United Kingdom would be reflected as land use carbon emissions in the totals of countries (mostly the United States) harvesting the inputs for the wood pellets and thus in their NIRs.[88]

To analogize, a country that obtains, such as through importation, and burns coal is supposed to report the ensuing carbon emissions in their NIR. A country that obtains, such as through importation, and burns wood pellets need not report the ensuing carbon emissions in their NIR. It is the country that exported the wood pellets that is supposed to report land use carbon emissions in their NIR.

Calculating land use carbon emissions is complicated.[89] Some experts report it is more technically difficult to measure carbon emissions from land use than from energy combustion.[90] Energy emissions, for instance, can be measured by monitoring the smokestacks from which the carbon is released into the atmosphere. Land use calculations cannot specifically measure the carbon emissions, they estimate the changes in carbon stocks on the land where biomass is being harvested and removed. Most

[85] Pena, Bird, and Zanchi, "Improved Methods for Carbon Accounting for Bioenergy," 2011, Executive Summary.
[86] Lintunen and Uusivuori, "On the Economics of Forest Carbon," 2014, 3.
[87] UK Department of Business, Energy, and Industrial Strategy, "UK Greenhouse Gas Inventory, 1990 to 2019," April 2021, 140.
[88] UK Department of Business, Energy, and Industrial Strategy, "UK Greenhouse Gas Inventory, 1990 to 2019," April 2021, 144; Enviva, "Seeing the Forest," 11–12.
[89] Houghton, "Carbon Emissions from Land Use," 2012.
[90] Matthews, "Assessment of EU LULUCF Regulation," December 21, 2020, 23.

importantly, while energy-related carbon emissions are largely under full human control, land use carbon stock changes are impacted by both human activity and dynamic natural systems.[91]

Drax reported that in 2019, of the 15.166 million tons of carbon it emitted, 12.795 million tons[92] (84.3 percent) were "biologically sequestered carbon" or "biogenic carbon emissions."[93] In this context, biologically sequestered carbon and biogenic carbon emissions are the carbon emissions from burning wood pellets. In 2020, Drax reported that its total carbon emission totals increased to 16.353 million tons, of which 13.273 million tons (81.2 percent) were biologically sequestered carbon.[94] Since Drax imports a large amount of wood pellets from the United States, it is likely that a large amount of its carbon emissions—caused by the burning of wood pellets at Drax factories—would be allocated to the United States under the UNFCCC and EU measurement methodology.[95]

# Wood Pellet Life Cycle Carbon Emissions

A holistic method of estimating a product's carbon footprint is called 'life cycle carbon emissions.'[96] Quantifying an energy product's life cycle carbon emissions is, however, complex, and fraught with disagreement. Generally, it entails calculating the aggregate of all related carbon emissions subtracted by the aggregate of all related carbon removal. Carbon emissions broadly include supply chain-related emissions (harvesting, manufacturing, and transportation) and energy-related emissions (combustion). Carbon removal broadly includes the amount of carbon removed from the atmospheric, such as through sequestration by the relevant trees.[97]

The biomass life cycle carbon emissions complexity is unique in energy product carbon life cycle analysis. There is little disagreement that energy sources like solar, wind, geothermal, hydro, and nuclear, emit low levels of carbon compared to fossil fuels.[98] In contrast, there is significant disagreement on whether

[91] Matthews, "Assessment of EU LULUCF Regulation," December 21, 2020, 23–31.
[92] Drax, "Annual Report 2020," March 5, 2021, 50; Miller, "The Millions of Tons of Carbon Emissions," December 8, 2021.
[93] Drax stated that the "biogenic carbon emissions resulting from generation are counted as zero in official reporting to both UK authorities and under the European Union Emissions Trading System (EU ETS) as the use of sustainable biomass is considered to be CO2 neutral at the point of combustion." Drax, "Annual Report 2020," March 5, 2021, 50.
[94] Drax, "Annual Report 2020," March 5, 2021, 50; Miller, "The Millions of Tons of Carbon Emissions," December 8, 2021.
[95] Analysis of whether the carbon emissions emanating from the combustion of U.S. wood pellet exports are fully counted in the U.S. NIR (U.S. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks," 2021) as land use emissions is beyond the scope of this paper. The subject is discussed in, among other papers, Brack, Birdsey, and Walker, "Greenhouse Gas Emissions from Burning US-Sourced Woody Biomass," October 2021, 21–22; Enviva, "Seeing the Forest," May 2020, 11–12; McKechnie, Colombo, and MacLean, "Forest Carbon Accounting Methods and the Consequences of Forest Bioenergy for National Greenhouse Gas Emissions Inventories," December 2014; Norton et al., "Serious Mismatches Continue Between Science and Policy in Forest Bioenergy," 2019.
[96] All energy types emit some carbon during their life cycle. For instance, solar and wind power—which emit no carbon when generating power—may emit carbon when the wind turbines or solar panels are manufactured, transported, or discarded. Overall, however, solar and wind power have much lower life cycle carbon emissions than fossil fuels. Pehl et al., "Understanding Future Emissions from Low-Carbon Power Systems," 2017.
[97] Sterman, "Does Replacing Coal with Wood Lower $CO_2$ Emissions?," 2018.
[98] Pehl et al., "Understanding Future Emissions from Low-Carbon Power Systems," December 2017.

biomass has a high or low (or zero or negative with carbon capture and storage) carbon emissions.[99] Some contend that biomass has a substantial carbon footprint akin to fossil fuels. Others, however, contend wood pellets are more like renewables and are net-zero carbon emitters. For instance, Enviva has stated on its website that "products from the Southeast U.S., including wood bioenergy, are not adding carbon emissions to the atmosphere. As a result, when wood pellets from this region are used to generate energy, we can set stack[100] emissions to zero."[101]

Some analysts suggest biomass related carbon emissions contribute to a 'carbon debt.'[102] A carbon debt is the total carbon emissions of an energy product. Under this concept, the carbon debt would ideally be paid off over time (the 'carbon payback time') through 'carbon dividends' to achieve a low-carbon or net zero carbon[103] impact on the climate.[104] Arguably, to achieve acceptance as a renewable energy with low or net zero carbon emissions, the emissions caused by the production and consumption of wood pellets (the carbon debt) should be paid off by trees acting as a carbon sink that store an equivalent amount of carbon that was emitted. In other words, the added atmospheric carbon should be absorbed by intentional reforestation or other means.

In a letter to the U.S. Congress in 2020, 200 scientists wrote that "current science finds that burning trees for energy produces even more $CO_2$ than burning coal, for equal electricity produced, and the considerable accumulated carbon debt from the delay in growing a replacement forest is not made up by planting trees or wood substitution."[105] In contrast, Enviva stated in a white paper that starting at the time of harvesting "does not account for the fact that harvests across a landscape are very dynamic and that regrowth occurs along with individual harvests, such that relevant accounting must be based on the integrated effect of all of the simultaneous harvest and regrowth events occurring in that wood basket."[106]

Critics of starting the carbon life cycle analysis at the time of harvesting also contend that it does not capture the entire wood pellet carbon life cycle and should start earlier, namely that it should include the forest growth before harvesting.[107] Thus, an important assumption to make relates to when the clock starts on the wood pellet carbon life cycle, particularly related to what does 'carbon removal' include. A simple model, that only includes trees intended for transformation into wood pellets and which entails two options, illustrates this. One option is that the carbon life cycle begins at the time of harvesting. A second option is that the life cycle should begin when the original trees—the ones that will eventually be used to manufacture wood pellets—are saplings, whether natural or planted by humans.

Under the first option, the estimations of the time it takes to retire a carbon debt vary and depends on a range of factors, such as the type of tree species and the longevity of the newly planted trees. For

[99] Cornwall, "Is Wood a Green Source of Energy?," January 5, 2017.
[100] Stack emissions are emissions that occur at the time of combustion.
[101] Enviva, "Carbon Accounting," accessed December 10, 2021.
[102] Manomet Center for Conservation Sciences, "Biomass Sustainability and Carbon Policy Study," June 2010, 6.
[103] Achieving "net zero carbon" (also known as "carbon neutrality") means "to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases." See UNFCCC Paris Agreement, 2015, Article 4.1.
[104] Schlesinger, "Are Wood Pellets a Green Fuel,?" March 28, 2018, 1.
[105] Moomaw, Letter to Members of U.S. Congress, May 8, 2020.
[106] Enviva, "Seeing the Forest," May 2020, 13.
[107] Strauss, "How Manomet Got It Backwards," May 2011, 4.

instance, one study estimated the carbon payback time for wood to range from 44 to 104 years from the time of clearcutting, if the forest is replanted.[108] Under this scenario, the carbon debt for wood pellets burned would be paid off between 2066 and 2126.

Under the second option, the carbon removed from the atmosphere by these trees would in essence create a carbon credit. Thus, the burning of biomass would be returning to the atmosphere carbon that the trees had previously absorbed from the atmosphere. The credit would be fully eroded once these trees are harvested, turned into wood pellets, and burned for energy. Theoretically, this would achieve net zero emissions over the entire—and lengthy—period.

# Biodiversity, Soil Health, and Tree Longevity

Beyond the carbon life cycle model, some suggest considering the impacts of monoculture reforestation. Scientists have reported that purposeful planting of monoculture trees for future biomass harvesting can have additional negative environmental impacts, such as being detrimental for biodiversity and soil health.[109] There are additional complications. For instance, to reduce the carbon debt over time, replanted trees must endure. In other words, if they succumb to wildfires or beetle infestations, as many trees are doing in a warming world,[110] their ability to pay down the carbon debt is diminished or eliminated. In addition, if the replanted trees are culled for other commercial reasons—such as agriculture or real estate—the carbon debt would be again incurred.

# Bioenergy With Carbon Capture and Storage (BECCS)

One concept for conceivably reducing the carbon footprint of products such as coal and wood pellets is to prevent or limit the carbon emissions triggered by combustion from entering the atmosphere. The carbon capture and storage (CCS) concept entails capturing the carbon emissions from energy production and storing them so that they do not add to atmospheric carbon levels. What this would mean in practice is that after fossil fuels or biomass are burned, the ensuing carbon emissions are first captured, such as in a smokestack. The captured carbon is then transported to a destination, generally by pipeline. The carbon is then stored in a suitable geologic storage formation, generally underground or below an ocean. This activity can theoretically have some profit motive. For instance, the captured carbon dioxide can be injected into depleted oil reservoirs for extracting oil; this is called tertiary or enhanced oil recovery (EOR).[111] Although the capture, transport, and storage of carbon emissions is technologically feasible, integrating the three practices is currently challenging and extremely expensive.[112]

The U.S. Department of Energy, under the Trump Administration, provided $1.1 billion in funding for coal-fired power plant CCS demonstration projects. This led to eight projects, one of which—Petra

[108] Sterman, "Does Replacing Coal with Wood Lower $CO_2$ Emissions?," 2018, 1.
[109] Liu, Kuchma, and Krutovsky, "Mixed-Species Versus Monocultures in Plantation Forestry," July 2018.
[110] Scott and Ireland, "The Tremendous Wooden Rollercoaster," November 2021.
[111] U.S. DOE, "Carbon Dioxide Enhanced Oil Recovery," March 2010.
[112] IPCC, "Carbon Dioxide Capture and Storage," 2005.

Nova—became operational.[113] The Petra Nova project sought to capture the emissions from a coal-fired power plant near Houston, Texas and use the captured carbon for EOR. Due to chronic mechanical problems and high expenses, however, Petro Nova was shuttered in 2020.[114] The only other major coal-fired power plant CCS facility operating globally, the Boundary Dam Power Station in Saskatchewan, Canada, has also faced challenges. Boundary Dam's CCS was established in 2014 and aimed to capture 90 percent of its carbon emissions for EOR use in nearby oil fields. It never reached this objective and, in 2021, it experienced mechanical problems and captured less than 50 percent of the facility's emissions.[115]

The biomass industry has also raised the possibility of CCS to capture carbon emission from burning biomass. In the context of bioenergy, this practice is called bioenergy with carbon capture and storage (BECCS).[116] If BECCS attained technological proficiency and cost affordability, it could potentially dilute the amount of carbon emitted by burning wood pellets. The idea of BECCS to reduce the carbon emitted by burning wood pellets, however, is still in its infancy. Moreover, the effectiveness and efficiency of BECCS remains unproven. Drax representatives have stated that, assuming receipt of subsidies from the UK government, it hopes to have a BECCS system operational by 2027.[117]

# The U.S. Infrastructure Investment and Jobs Act and Reconciliation Bill

The U.S. Infrastructure Investment and Jobs Act, which became law in November 2021, included financial support for the biomass industry and BECCS via funding and tax credits.[118] In addition, the infrastructure law provided that $400 million be made available to the U.S. Secretary of Agriculture to provide financial assistance to facilities (such as biomass facilities) that purchase and process byproducts from "ecosystem restoration projects."[119] A draft U.S. reconciliation bill also included financial support for the biomass industry, and generated starkly opposing views.[120] At the time of writing, the reconciliation bill had not become law.

# Outlook

More so perhaps than any other purportedly climate change ameliorating energy product—apart perhaps from nuclear energy—wood pellets have triggered acrimony between advocates (such as the EU and industry representatives) and critics (such as environmentalists and many scientists).

[113] U.S. GAO, "Carbon Capture and Storage," December 2021.
[114] Wamsted and Schlissel, "Petra Nova Mothballing Post-Mortem," August 2020.
[115] Rives, "Only Still Operating Carbon Capture Project," January 6, 2022.
[116] Azar et al., "Carbon Capture and Storage from Fossil Fuels and Biomass," 2006.
[117] Drax, "Drax to Invest £40 million," December 15, 2021; Miller, "The Millions of Tons of Carbon Emissions," December 8, 2021.
[118] U.S. Infrastructure Investment and Jobs Act, Sections 40301–40333 (Fuels and Technology Infrastructure Investments) and Section 80402 (Carbon Dioxide Capture Facilities).
[119] U.S. Infrastructure Investment and Jobs Act, Section 40804 (Ecosystem Restoration).
[120] Annand, "What's in Store for Biomass Power in 2022," February 3, 2022; Moomaw, "Open Letter," November 4, 2021.

Interlocutors especially disagree on how to measure wood pellet life cycle carbon emissions. Consequently, more attention may be given to whether global carbon emission totals are accurately counting wood pellet related land use emissions that are not being counted as combustion emissions. Moreover, the proportion of wood pellet feedstock that comes from trees felled purely for transformation into wood pellets and the proportion that comes from forestry residues, remains debated as there is currently limited definitive information on these proportions. Policy analysis might also benefit from more discussion on the impacts of wood pellet production on biodiversity, soil health, and air quality. Thus, due to the complexity, myriad needed assumptions, and relatively small industry size compared to fossil fuels, deliberations on the environmental impacts of wood pellets have not yet reached a crescendo. Discord will thus likely persist on whether wood pellets should continue to be a feature of the climate change strategies of the EU, United Kingdom, Japan, South Korea, and others, and of U.S. forest product exports.

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