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BioTrade2020plus

Supporting a Sustainable European Bioenergy Trade Strategy

Intelligent Energy Europe

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Deliverable WP 3

Biomass Use and Potential for export to the European Union from 2015 to 2030

United States Southeast – Case Study

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The BioTrade2020plus Project

Objectives

The main aim of BioTrade2020plus is to provide guidelines for the development of a **European Bioenergy Trade Strategy for 2020 and beyond** ensuring that imported biomass feedstock is sustainably sourced and used in an efficient way, while avoiding distortion of other (non-energy) markets. This will be accomplished by analyzing the potentials (technical, economical and sustainable) and assessing key sustainability risks of current and future lignocellulosic biomass and bioenergy carriers. Focus will be placed on wood chips, pellets, torrefied biomass and pyrolysis oil from current and potential future major sourcing regions of the world (Canada, US, Russia, Ukraine, Latin America, Asia and Sub-Saharan Africa).

BioTrade2020plus will thus provide support to the use of stable, sustainable, competitively priced and resource-efficient flows of imported biomass feedstock to the EU – a necessary pre-requisite for the development of the bio-based economy in Europe.

In order to achieve this objective close cooperation will be ensured with current international initiatives such as IEA Bioenergy Task 40 on "Sustainable International Bioenergy Trade - Securing Supply and Demand" and European projects such as Biomass Policies, S2BIOM, Biomass Trade Centers, DIA-CORE, and PELLCERT.

Activities

The following main activities are implemented in the framework of the BioTrade2020plus project:

- Assessment of **sustainable potentials of lignocellulosic biomass** in the main sourcing regions outside the EU
- Definition and application of sustainability criteria and indicators
- Analysis of the main economic and market issues of biomass/bioenergy imports to the EU from the target regions
- Development of a dedicated and **user friendly web-based GIS-tool** on lignocellulosic biomass resources from target regions
- **Information to European industries** to identify, quantify and mobilize sustainable lignocellulosic biomass resources from export regions
- **Policy advice on long-term strategies** to include sustainable biomass imports in European bioenergy markets
- **Involvement of stakeholders** through consultations and dedicated workshops

More information is available at the BioTrade2020plus website: **www.biotrade2020plus.eu**

About this document

This report is one of the six case studies developed under WP3 of the BioTrade2020+ project

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List of Acronyms

ACB	All Biomass Constrained (implementation scenario)
AEO	US Department of Energy's Annual Energy Outlook
ARA	Amsterdam Rotterdam Antwerp
BAU	Business As Usual (scenario)
BTU	Billion Ton Update
CHP	Combined Heat and Power
CIF	Cost, Insurance and Freight
DECC	UK Department of Energy & Climate Change
EBC	Export Biomass Constrained (implementation scenario)
EC	European Commission
EIA	Energy Information Administration (US Department of Energy)
EPA	US Environmental Protection Agency
EU	European Union
FPM	Forest Products Module
FRSC	Fuel Reduction Cost Simulator
GDP	Gross Domestic Product
GHG	Greenhouse gases
ha	hectare
HT	High Trade (scenario)
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
LCA	Life-cycle Assessment
Mt	Million metric tonnes
OSB	Oriented strand board
PJ	PetaJoules
RPA	Resource Planning Act
SRTS	Subregional Timber Supply

SCF	Sustainability Constraint Factor
TPO	Timber product output
t	Metric tonne (1000kg)
UN ECE	United Nations Economic Commission for Europe
UN FAO	Food and Agriculture Organization of the United Nations

1 Introduction

The main objective of the BioTrade 2020+ Work Package 3 is to analyze the technical and sustainable potentials for import of biomass/bioenergy feedstocks from selected source industries and regions. These assessments consider the main economic, biophysical, and market drivers affecting biomass availability for the six designated biomass sources described in *Table 1*. The selection of regions and feedstocks for investigation was based on literature review, partners' previous work in the selected countries and information provided by the Advisory Board members. This report focuses on forest biomass from the Southeastern United States.

Table 1: Summary of countries and feedstock potential

Country	Feedstock				
	Forest residues	Agricultural residues	Forest plantations	Biomass crops	New forest plantations
Brazil		√		√	√
Colombia		√		√	
Kenya		√	√	√	
Indonesia		√			
United States	√		√		√
Ukraine	√	√		√	

Source: own elaboration

The main drivers of biomass availability and cost in these case study regions are:

- Current and projected future production of selected biomass types
- Policy constraints aimed at addressing the environmental and social impacts of biomass sourcing
- Industry dynamics as well as physical and logistical constraints limiting utilization of materials
- Market demand for biomass for energy and other uses both in the source country as well as in third-country trading partners

These drivers vary strongly between the different case studies, and also data availability ranges from very good to poor. While the approach to the issues above differs somewhat between the BioTrade 2020+ WP3 case studies, they all determine a net sustainable export potential of biomass and related cost and GHG supply curves as elaborated in the project (see Mai-Moulin et al. 2014).

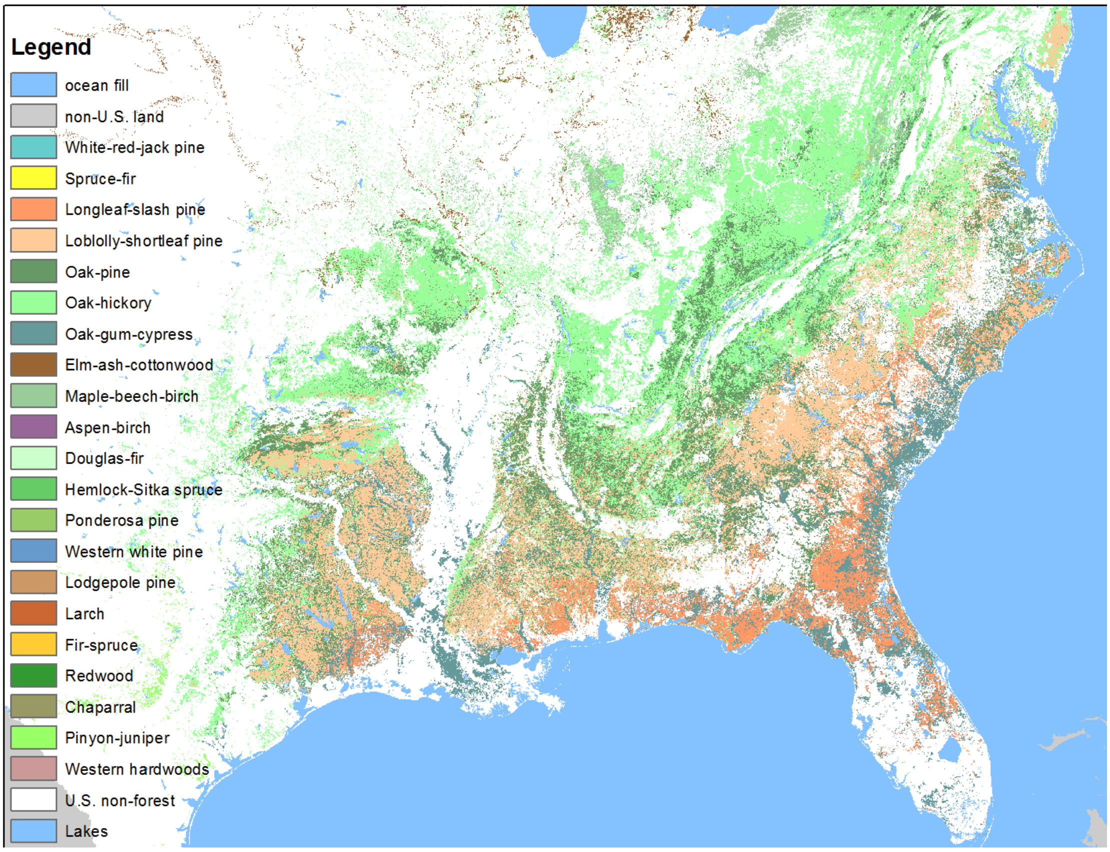
1.1 Forests and forestry in the US Southeast

The United States Southeast (US SE) gained a lot of attention from the traditional forest sector in the US as of the late 1980s and 1990s as biodiversity conservation efforts focused especially around the Northern Spotted Owl *(*Strix occidentalis caurina*)* led to a significant decline in timber harvest throughout the US Pacific Northwest (Thomas et al. 2006). Production attention shifted strongly to the Southeast, and led to further investments in plantations. As a consequence, both plantation area as well as growth rates of slash pine and loblolly pine increased. Current forest types of the US SE are illustrated in **Error! Reference source not found.**.

Even though the plantations are only about 30% of the total forest area, their (stemwood) volume increment is more than 2/3 of the total regional increment (

Table 2). But about 75% of that increment is already harvested for industry or lost due to mortality. The US SE generates 60% of the US annual timber harvest (Conrad et al. 2011). In most US SE States, plantation area has been fairly stable in recent years (Abt, Abt & Galik 2013; Macedo 2013).

Figure 1: Forest types of the US Southeast



Source: USDA Forest service fia.fs.fed.us

Note: The total forest area is some 100 million ha. Brownish/pink colors are the longleaf-slash pine and loblolly-shortleaf pine plantations, covering close to 30 million ha. The dark green at the coast is native bottomland hardwoods of oak-gum-cypress. More inland light and dark green are oak-hickory and oak pine forests.

Table 2: Forestry overview statistics for the US South[1]

	Forest area, Mha	Net annual stemwood volume increment, Mm^3	Fellings (pulplogs and sawlogs), Mm^3	Mortality, Mm^3
Total South	100	364	224	78
Longleaf and shortleaf pine plantations	29	246	148	33

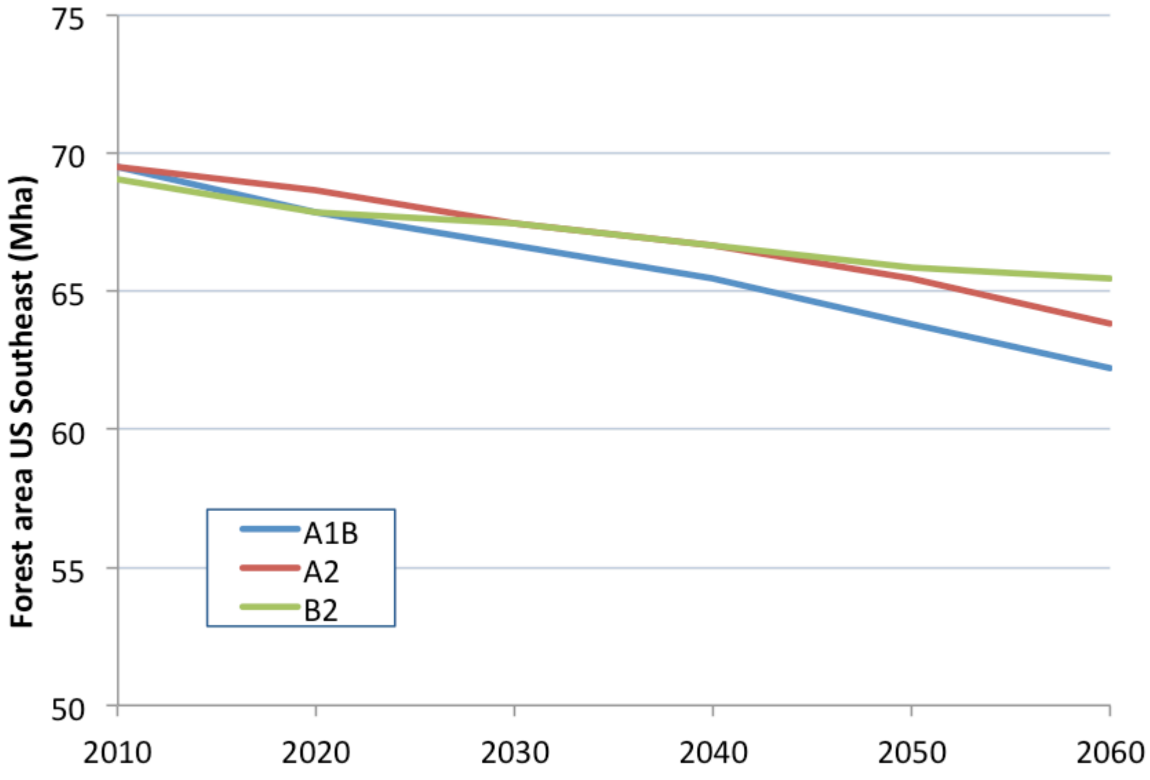
Source: USFS (2012)

Despite economic development and growing population, the total amount of forested land in the US has remained largely unchanged throughout the past century. However, increasing development and continuing population growth are expected to drive a reduction in forest area in the near future. The 2010 Resource Planning Act (RPA) Assessment projected reductions in total forestland within the US south ranging from 3.6 to 7.2 Mha, or about 5-10% by 2060 (USFS 2012).

Upland hardwood forests are expected to decline in particular as population growth and urbanization pressures expand in the area. These projected reductions in forestland occurred across all scenarios considered in the RPA Assessment. The primary exception in these projected losses across the US SE is the area of pine plantation, which is expected to grow (USFS 2012). Figure 2 presents total forestland expected under the different scenarios considered under the 2010 RPA Assessment. These scenarios vary in their projections of global and US economic and population growth as well as the global development of the bioenergy industry. These scenarios are described in section 2.1.2 of the present report (for more detail, see USFS 2012 and Nakicenovic & Swart 2000).

[1] Different analyses and datasets in the forestry space cover different specific regions. The nationwide Resource Planning Act Assessment published every five years by the USFS includes all of TX and OK in the region it defines as the "South." These two states are outside the boundaries of this analysis, however, as they are in a different ecoregion than the rest of the Southeast study region (see Figure 11) and have not been a major source of biomass supply to the EU in the past.

Figure 2: Total projected forestland in the US South per the three main 2010 Resource Planning Act Assessment scenarios for the forest area in the US South.



Source: Wear (2011)

1.2 US Forest products market

Historically, the US has been both the largest producer and the largest consumer of woody biomass in the world. The US share of global wood product production peaked at 28% in 1998 and has since fallen to below 20% (Prestemon et al. 2015). The amount of roundwood required for wood and pulp product demand in the US has roughly tracked population growth, (Skog et al. 2012), and the total roundwood equivalent volume to meet US wood and paper materials demand was roughly stable through the latter half of the 20th century (USFS 2012). US imports of sawnwood products rose in the early part of this century, as a gap began to grow between domestic production and demand. However, consumption of these products has dropped in recent years. The primary driver of this downturn was the reduction in housing starts[2] beginning in 2005, exacerbated by the 2008 financial crisis as well as the shift away from print towards digital media (USFS 2012). Figure 3 presents the

[2] A common indicator of economic activity, the "housing start" is defined as the commencement of construction on a new residence during a given period.

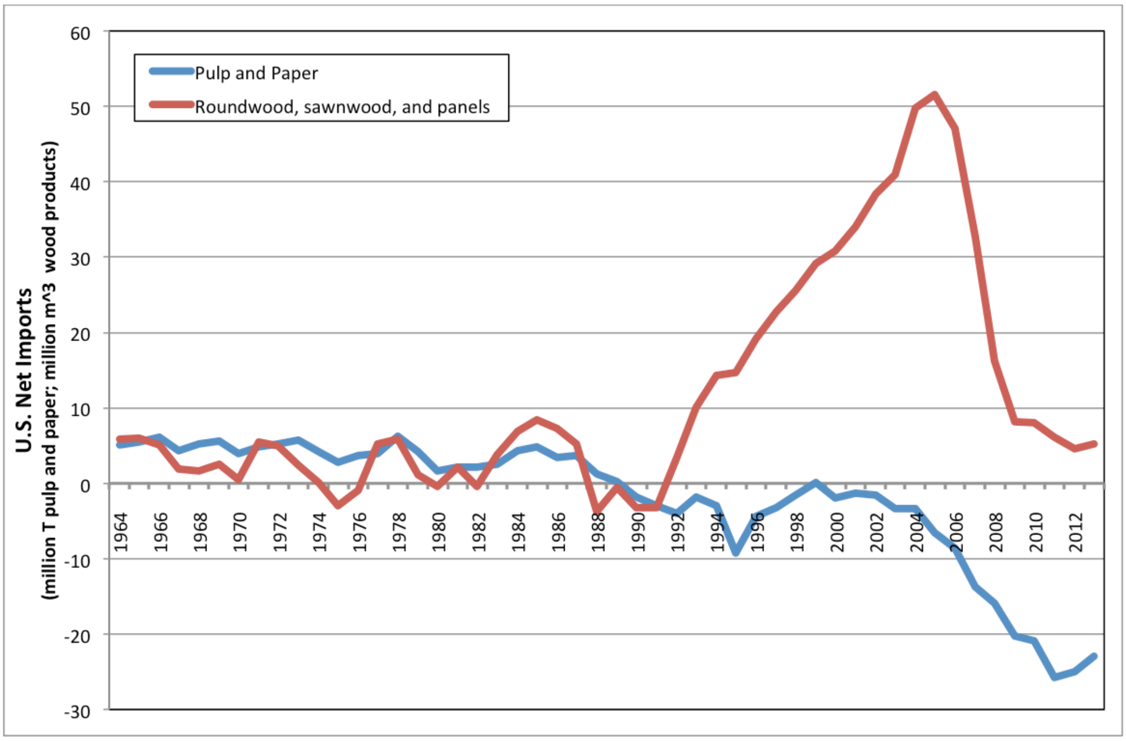
trends in net import levels for solid wood products as well as pulp and paper for the United States over the past 50 years.

Timber demand is most closely correlated with housing starts, and it is still over 25% lower in the US than it was at its peak before the collapse of the housing market. While there has been some recent recovery, several factors combine to reduce the total wood demand for US housing (adapted from Skog et al. 2012):

1. Much of the recent rise in housing starts has been in multi-unit dwellings, which require less total wood per unit, as they are smaller on average and share structural elements. While 18% of housing starts from 1998-2006 were more than four units, this figure is 32% for starts since 2012.
2. Residences started in 2009-2013 were on average 9% smaller than similar starts from 1998-2006.
3. Engineering and construction technique have shifted over the past half century, leading to a 50% reduction in wood use per ft^2 of usable space.

Pulp and paper markets in the US correlate most closely with overall trends in manufacturing; both peaked in 1998. Paper production has dropped off even more precipitously, owing to the combination of macroeconomic trends such as the drop in overall manufacturing and the ongoing shift towards electronic media (Prestemon at al. 2015). Consumption of newsprint has been falling since the 1980s, with printing and writing papers joining in the early 2000s. This decline in newsprint consumption has to a large degree been compensated by a rise in demand for pulp for cardboard packaging. Most recent signals show a stable to small increase in overall consumption of pulp and paper again (UNECE 2015).

Figure 3: United States Net imports of wood products and pulp/paper products since 1964



Source: own elaboration from UNECE-FAO (2015) database

Note: Much of the increase in net pulp and paper export through recent years is due to a rise in the collection and export of "recovered" paper through recycling which currently stands at approximately 20 million tonnes exported annually.

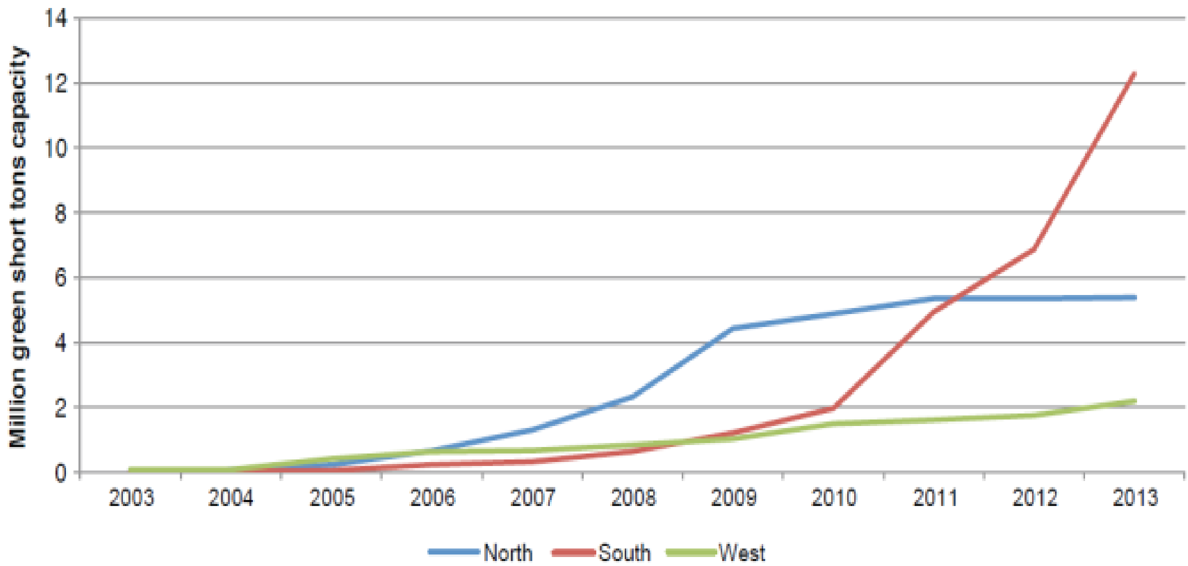
The large-scale trends in the markets for US forest products have also had an impact on the regional distribution of forestry activities. A shift from solid sawnwood towards engineered wood products has enabled an increase in the proportion of smaller-diameter trees in timber harvest. This has led to a shift away from the Pacific Northwest region, which was once the centre of the US forest products industry towards plantation operations in the Southeast. In the decade between 1986 and 1996, the fraction of US timber harvest in the Northwest region dropped from 26% to 15% (Haynes 2003).

The use of wood for energy in the US was 2,336 PJ in 2014 or about 146 million dry tonnes of wood. This represents 2.2% of total energy and 23% of renewable energy use. While this was a 2% increase from 2013, it is still 18% below the 1985 peak (UNECE-FAO 2015). While most of the increase is coming from increasing pelletization and generation of bioelectricity, the majority of the wood use for energy is still for home heating. Approximately 2.1% of US households are heated primarily with wood, and another 7.7% use it as a supplemental heating source. Most of this use is as split logs, though the use of bagged pellets for home heating is on the rise (UNECE-FAO 2015).

1.3 Pellets markets and trade

During the past decade, pellet production has increased throughout the US, and especially in the Southeast region (see **Error! Reference source not found.**). This expansion has been in large part a response to the increasing EU market demand. In 2014, US wood pellet production was estimated at 6.9 million tonnes (Mt) – an increase of about 21% from 2013 (UNECE-FAO 2015). Of this material, about 4.7 Mt was exported, 98% of which was from the US South region (Wang et al. 2015). As of 2015, 9.1Mt/yr of pelletization capacity is currently operational in the country (UNECE-FAO 2015).

Figure 4: Growth in pellet production capacity by US region from 2003 through 2013.

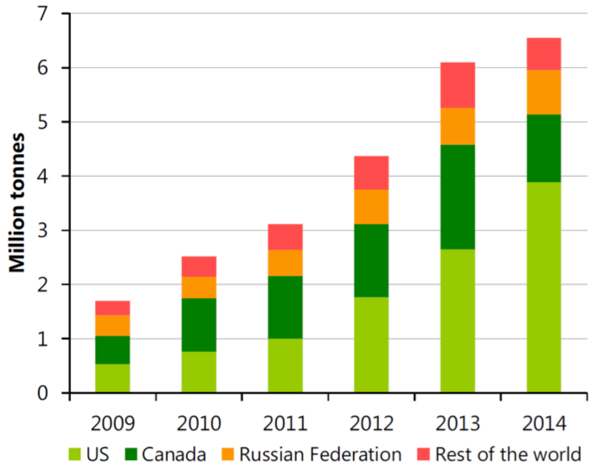


Source:Forisk Consulting (2014) in: Abt et al. (2014)

Note: Amounts are presented in green short tonnes. Pellet production would be roughly half of these figures.

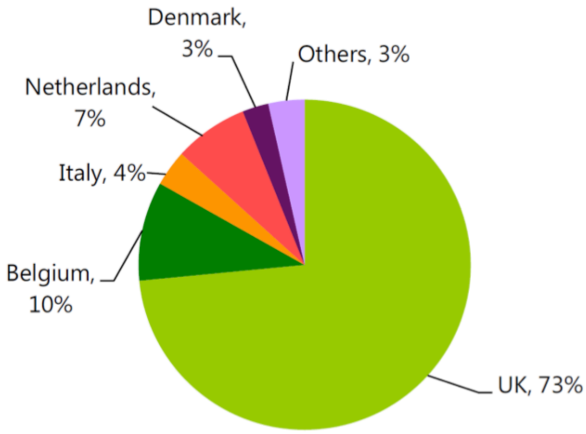
Pellet exports from the US to the EU have increased 6-fold since 2008 (Wang et al, 2015). As illustrated in **Error! Reference source not found.**, the US has become the primary source of pellets to EU markets, representing more than 60 percent of the total wood pellet imports to the EU in 2014. The UK is the primary import market for pellets from the US SE, followed by Belgium and the Netherlands, as shown in **Error! Reference source not found.** (UNECE-FAO 2015).

Figure 5: EU 28 imports of wood pellets, 2009-2014



Source: UNECE-FAO (2015)

Figure 6: Top five importers of US pellets (2014)



Source: UNECE-FAO (2015)

The trend towards expanding woody biomass production and export from the US SE region is expected to continue. The forward projections conducted for the US Forest Service's 2010 Resource Planning Act (RPA) Assessment (USFS 2012), anticipate that the South region will continue to be the primary timber region in the country. In all of the RPA scenarios considered, the region was projected to account for over 50% of total national timber harvest, including the majority of bioenergy feedstock production.

Most woody biomass burned for energy, and nearly all of that exported for this purpose, is in the form of biomass pellets, which are valued for their stability and energy density. By May 2015, installed wood pellet production capacity reached 9.1 million tonnes and by the end of the year was on track to top 11 million tonnes (COWI 2015). The vast majority of US wood pellet capacity is found in the Southeast. Several factors have led to the US industrial pellet sector growing mainly in the US SE and making it the most promising region for production of pellets for the EU market. These include (Forisk Consulting 2013; COWI 2015):

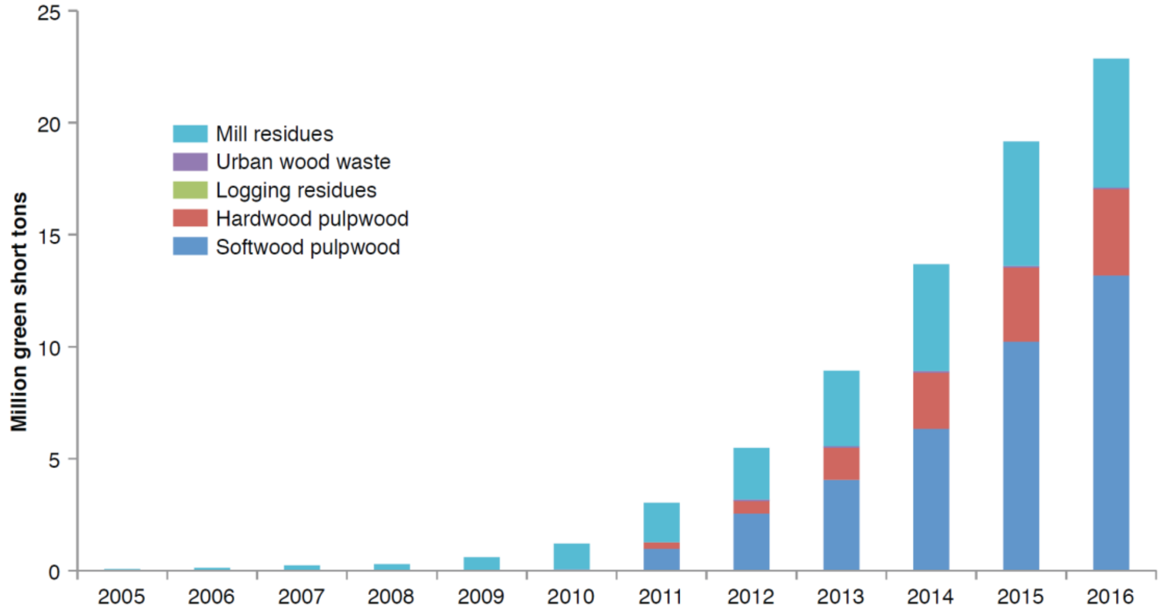
- The **response** of investors and project developers to current demand in the EU.
- The perceived **availability** of low-cost biomass (based on historical and current market data) especially given declines in paper milling industry,
- A well-developed forest products **industry** that could facilitate the acquisition of materials for pellets,
- Cost-effective **transportation** networks for both feedstock procurement and movement of finished product to export terminals.
- Attractiveness as an investment due to the relatively low levels of capital **investment** when compared to liquid fuel and large-scale electricity projects ($150 million or less vs. hundreds of millions of dollars).

Photo: The Enviva pellet mill in Ahoskie, NC. On the left, raw materials can be seen: low quality logs as well as saw dust and chips. Being located in a region with both short rotation industrial plantations as well as native bottomland hardwoods. The sourcing of this and similar facilities has come under heavy scrutiny (Hammel & Smith 2013) and could be impacted by EU biomass sustainability criteria.

Until 2010, mill residues represented the major feedstock for pellet production, but since 2011 both softwood and hardwood pulpwoods are also being used (Abt et al. 2014; Iriarte, Fritsche & Pelkmans 2014). In 2013, about 45% of the biomass for pellets in the US came from softwood pulpwood, about 15% from hardwood pulpwood and the remaining 40% from mill residues (Abt et al. 2014).

It is expected that the share of pulpwood feedstock will continue to increase. All these facilities have to rely on outside sources of wood (dealers/loggers, gatewood or stumpage purchases directly from landowners, either through spot markets or contracts). **Error! Reference source not found.** presents recent and projected feedstock use for pellet production in the US SE.

Figure 7: Feedstock source for use in pellet production in the US South for 2005–2016



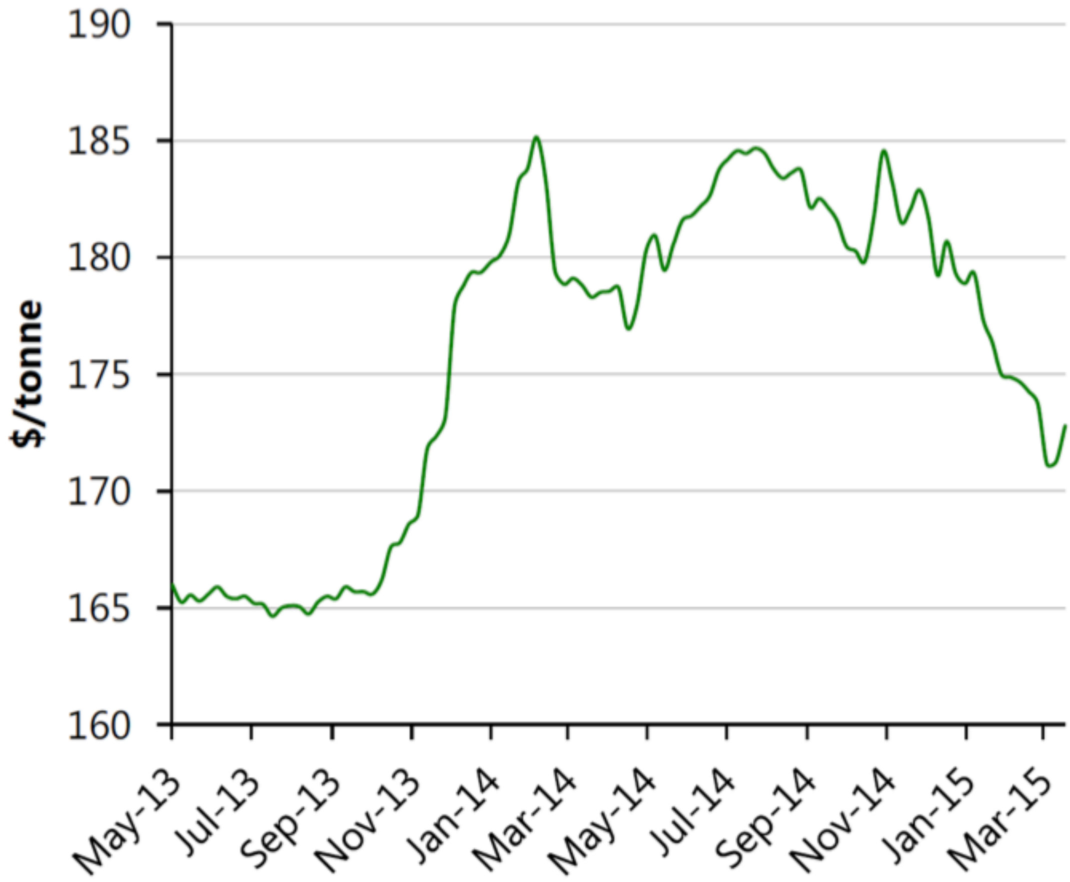
Source: Forisk Consulting (2014) in: Abt et al. (2014)

The economics of wood pellet production are complex, especially where high-quality feedstocks such as wood chips and mill residues are used. Pellet manufacturers must compete for these feedstocks with manufacturers of paper products and panel products such as particleboard and oriented strand board (USFS 2012).

While biomass pellets have, up to this point, been made almost exclusively from mill residues and pulpwood, lower quality resources such as harvest residues, are expected to become important, or even dominant, if the use of wood for energy increases significantly (USFS 2012).

While consumption of wood pellets has risen in the recent past, this has been offset by increased availability of wood pellets, keeping average wood-pellet prices under $200/tonne as illustrated in **Error! Reference source not found.**. Increased use of biomass for energy would lead to both tightening of biomass markets as well as the increased reliance on resources such as harvest residues and thinnings that are comparatively costly owing to the logistics associated with their collection and processing. The economic viability of these feedstocks hinges on the efficiency with which they can be harvested (Grushecky et al. 2007 in Galik & Abt 2015).

Figure 8: Wood pellet prices at Amsterdam, Rotterdam, Antwerp (ARA), May 2013-March 2015



Source: UNECE-FAO (2015)

1.4 Sustainability Considerations

Many forestlands of the US Southeast are biodiversity hotspots. The region has a relatively high rate (11%) of plant and animal species considered to be at-risk (i.e. vulnerable, imperiled, critically-imperiled, or thought to be extinct) (Wear & Greis 2002; NatureServe 2013). Some forest types of high conservation value on the Coastal Plain are bottomland and floodplain forests, gum-cypress, elm-ash-cottonwood, as well as some oak/hickory and oak/pine systems.

As reported in Deliverable 2.1 of the BioTrade2020+ project (Díaz Chavez 2015), species richness is highest in the Mid-South and Coastal Plain. Land use changes have occurred for several centuries in the region, and the fracturing of forestland combined with climate change have led to important impacts. In the near future, further shifts from natural forest to managed plantations might adversely affect endangered species in certain locations, but shifts from agricultural systems to forests might improve habitat conditions (Alavalapati et al. 2013).

Private landowners hold 86% of the forest area in the South, with two-thirds of this area owned by families or individuals (Butler & Wear 2013). A key point for reflection is that regulations in the US give significant freedom to landowners to make decisions in their forestlands. As such, owner behaviour might influence land use changes and management practices in any direction (e.g. from forest land to agriculture land or vice versa). Land use changes might significantly impact biodiversity (and other forest features). This study assumes that current harvesting statistics already reflect these dynamics, so this parameter will not be further considered in the analysis.

From a greenhouse gas (GHG) perspective, most life cycle assessment studies show some gains from displacing EU grid electricity with bioelectricity from US pellets. Dwivedi et al. (2014), for example, found generation of UK bioelectricity from US pine pellets to represent a life cycle emissions reduction of between 50% and 68%. Similarly, Wang et al (2015) found forest biomass pellets to offer a 74% life cycle GHG emission reduction when they replace coal in UK power generation. These findings are in line with the life cycle emissions calculated in the EC's own research conducted by its Joint Research Centre (Guintoli et al. 2015). A critical consideration with the numbers presented here is that this approach to calculating the life cycle GHG emissions from bioenergy systems considers combustion of biogenic fuels to be carbon neutral[3].

Some stakeholders (e.g. environmental NGOs, researchers, etc.) have questioned this approach[4]. However, following the current approach of the EC (see e.g. Giuntoli et al. 2015), we assume carbon neutrality for biomass combustion in this report. It is also worth noting that the deep emission reductions cited here are not certain: beyond decisions about biogenic CO_2 accounting, they depend upon sustainable forest practices as well as factors such as power plant capacity, age of the source forest, and the approach used in drying the biomass (Iriarte et al. 2016).

[3] Similarly, the US EPA also assumes carbon neutrality for solid biomass burnt in stationary sources (EPA 2014).

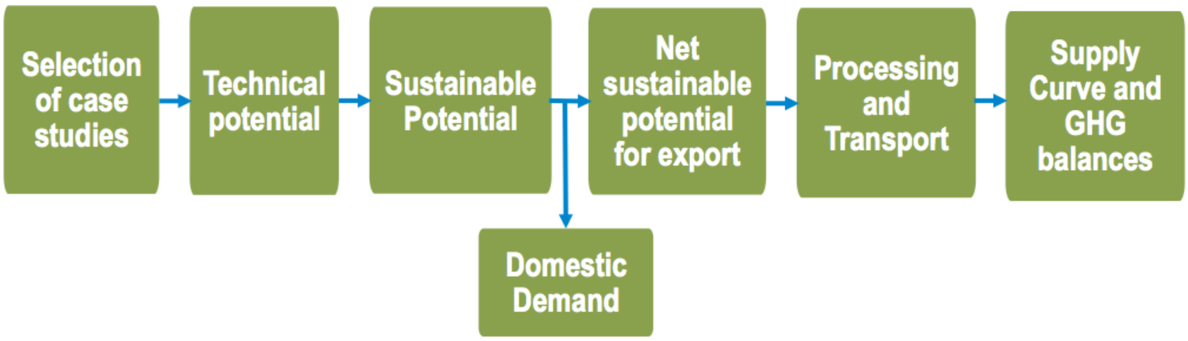
[4] For a critical discussion see e.g., Agostini et al, 2013, Buchholz 2015; Guintoli et al. 2015; Matthews et al. 2015; Röder, Whittaker & Thornley 2015).

2 Methods

Once the case studies for the BioTrade2020+ project were selected, we applied a common methodology to each of them in determining the sustainable potential for export to the EU (see **Error! Reference source not found.**). We calculate the technical potential according to the availability of the selected feedstock and the residue production ratio imputed from past production rates. This technical potential is then constrained to achieve sustainability goals depending on regional conditions and data availability. The overall methodology is illustrated in **Error! Reference source not found.** (and in more detail in the methodology report).

The following sections describe how this general methodology has been applied to the US SE case study.

Figure 9: Overall methodology of the Biotrade2020+ project for selected countries and regions.



Source: Adapted from Mai-Moulin et al. (2015)

The background information for the selected countries (see Deliverable 2.1) helped to identify the regions in each country that were more promising for the availability of the feedstock but also that included some of the technological facilities (including transportation and other logistics) to bring biomass to market. The information provided from the BioTrade 2020+ Advisory Board (AB) also contributed to selection of the source regions.

2.1 Assessment of biomass supply

2.1.1 Feedstock and county selection

This study focuses on biomass from forestry in the Southeastern US. We only include in our analysis those classes of biomass for which bioenergy could reasonably compete economically. This meant excluding material that is suitable for production of higher-value products, such as sawlogs (to be sawn into lumber) and veneer logs (to be lathed to make plywood).

The following classes of materials reported in the United States Forest Service (USFS) Timber Products Output (TPO) database were included:

- Both hardwood and softwood pulplogs
- “Composite products,” “fuelwood,” and “miscellaneous.[5]”
- Logging residues. This category includes identified volume as the residual portions of trees cut for roundwood products, excess small pole trees and other trees felled in the process of extracting roundwood products that are left on the ground after roundwood product harvests[6].
- Sawmill residues. This category includes identified volume as wood and bark residues generated by primary wood-using mills during the processing of roundwood into primary products, like sawnwood, veneer, and wood pulp.
- “Other removals[7].” This category includes identified volume as trees removed from the timberland inventory due to land use change to some non-forest use, and any trees felled in timber stand improvement activities, like pre-commercial thinnings, weedings, etc., that are not directly associated with roundwood product harvests.

For the purposes of this study, the US Southeast (US SE) is defined as the states of Alabama (AL), Arkansas (AR), Florida (FL), Georgia (GA), Kentucky (KY), Louisiana (LA), Missouri (MO), North Carolina (NC), South Carolina (SC), Tennessee (TN), and Virginia (VA).

See **Error! Reference source not found.** for a map of the states in the study region.

[5] These products are defined in the TPO database as:

- *Composite products* – “Roundwood logs, bolts, and chips used in the manufacture of reconstituted wood products.”
- *Fuelwood* – “Roundwood logs, bolts, and chips used as fuel in industrial, residential, and institutional situations.”
- *Miscellaneous* – “Roundwood logs, bolts, and chips processed into a variety of products not previously listed.”

[6] It should be noted that forest residues have a high concentration of bark (because of their high surface to volume ratio) as well as soil and other debris. These materials can cause slagging, fouling and corrosion in boilers (Stephenson & MacKay 2014), and are therefore not a preferred fuel. There remains some uncertainty as to the extent to which these materials will be able to be made useful as bioenergy feedstocks.

[7] The “other removals category in the TPO database is defined as “unutilized wood volume of trees cut or otherwise killed by cultural operations (e.g. pre-commercial thinnings) or land clearings to non-forest uses.”

Figure 10: States in the US SE study region

Source:Own elaboration

Different analyses and datasets in the forestry space cover different specific regions. For example, the US SE region in the USFS TPO database covers the above states as well as the eastern portions of Texas (TX) and Oklahoma (OK). The nationwide Resource Planning Act Assessment published every five years by the USFS includes all of TX and OK in the region it defines as the "South."

However, the majority of TX, and all of OK are in the "Mid-south" ecoregion (**Error! Reference source not found.**), and these areas have not been a major source of biomass supply to the EU in the past. Therefore, these are not included in this analysis.

Figure 11: Forest ecoregions of the Southern US

Source: Wear & Greis (2013)

2.1.2 Technical potential

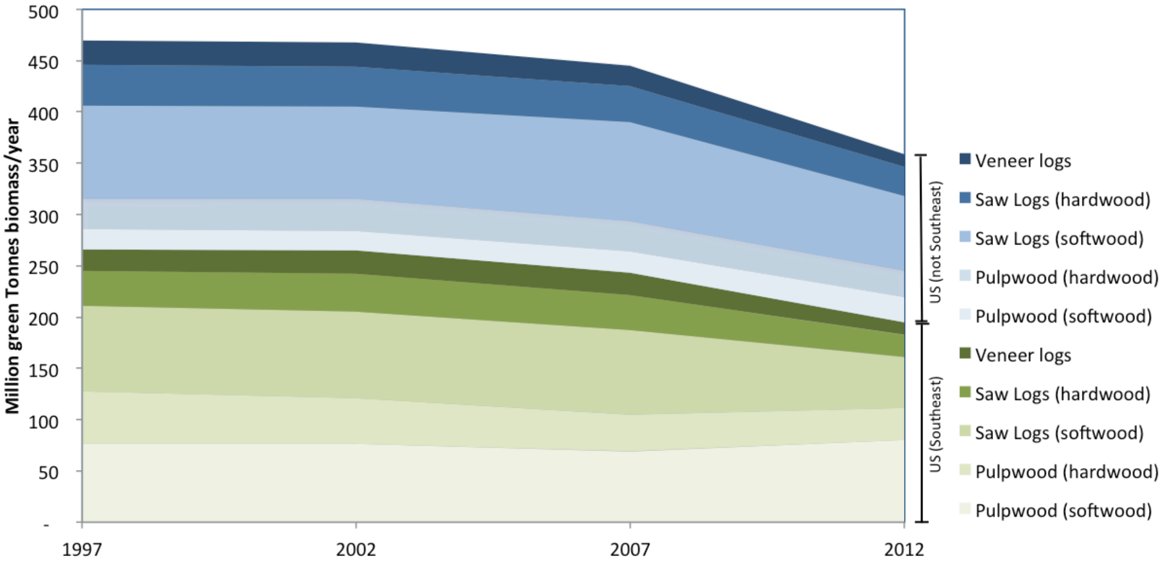
The technical potential is defined here as all of the biomass suitable for bioenergy that is available in the region without considering sustainability or feasibility of its delivery. Next, some very basic no-go sustainability/feasibility constraints are applied by not counting in the technical potential any biomass derived from:

- Deforestation/land clearing operations
- Illegal cutting on protected lands, or
- Removal of more than 67% forest residues (Perlack 2011).

Further, we estimate potential biomass supply here, and therefore *do not constrain the supply to current or projected future pelletization capacity or supply chain sufficiency.* Pellet mill capacity development over the coming 15 years will be driven by demand, which will in turn be driven by energy and climate policy. Hence, this analysis seeks to project various scenarios of technically available supply without considering market capacity (e.g. pelletization and supply chain capacity). Given this, the estimates presented might in some cases be higher than those seen in pellet supply projections, and should, therefore, be understood to set a sort of a "ceiling" on actual pellet availability.

Historical data on forest product removals were drawn from the US Forest Service Timber Products Output (TPO) database (USDA-USFS 2015). Baseline/historic production levels were collected at a county-level resolution throughout the US SE region from the TPO database for the years 1995-2009. Nationwide data are reported less frequently through the RPA process, so these data were extracted for RPA years 1997, 2002, 2007, and 2012. These reports collate and average data collected by regional offices across the study period, so are not necessarily representative of the report year, but they do offer a good first-order approximation of different types of forestry removals across the US. **Error! Reference source not found.** presents these baseline nationwide data.

Figure 12: US national roundwood removals by class and region (1997-2012).



Source: Own elaboration based on data from USFS Timber Products Output database.

As described in Section 2.1.1 above, the following classes of materials and respective assumptions were included:

- Both hardwood and softwood pulplogs
- “Composite products,” “fuelwood,” and “miscellaneous.”
- Logging residue at a 50% removal level for BAU (Galik, Abt, & Wu 2009) and 67% level for the high trade case (Perlack 2011)[8].
- Sawmill residues.
- “Other removals” (at a 50% removal level for both cases, see Hoefnagels 2014).

The “other removals” estimates are derived from average annual removals data for the latest forest inventory of each State. Average annual removals estimates are made for the time period between two successive State forest inventories, usually about 10 years, and are therefore short-term historic averages and not estimates for a specific year. These average

[8] See section 2.3 for a detailed description of the differing study scenarios.

annual removals estimates are also based on sampling procedures designed to provide reasonable estimates of total forest area and total timber inventory in a State.

Spatially discrete projections of current-year and future forest product production at a county scale were derived from the Subregional Timber Supply (SRTS) Model (Abt 2000). The baseline SRTS outputs were used to describe the business as usual (BAU) production case with high-biomass supply case derived from the joint US and global Forest Products Module (FPM) model (Ince 2011) runs and scenarios developed for the 2010 USFS Resource Planning Act Assessment[9] (USFS 2012). This USFS modelling effort projected future forest product harvest and demand under different Special Report on Emissions Scenarios (SRES) developed by the IPCC (Nakicenovic and Swart 2000). Parameters in the FPM relating to global and domestic population growth, GDP, global trade patterns, bioenergy use, and climate were tied to those applied in the SRES scenarios. The two primary RPA/SRES scenarios used in this analysis are the RPA A1B and RPA B2 scenarios, the key characteristics of which are described in Table 3 below.

Table 3: Main characteristics of the RPA/SRES scenarios used in this analysis

	RPA A1B	**RPA B2**
General scenario description	Globalization, economic convergence	Slow growth, localized action
Global real GDP growth (2010-2060)	High (6.2x)	Medium (3.5x)
US real GDP growth (2010-2060)	Medium (3.3x)	Low (2.2x)
Global expansion of biomass energy use	High	Medium

Source: adapted from (USFS 2012)

Some relevant data sources, such as the FPM model outputs used for the High Trade scenario, are only reported at the national scale. Where this was the case, historical patterns of US-wide and US SE region share of hardwood and softwood production, as well as RPA projections of future yield, were used to determine the US SE region “share” of total production. Where some of the above categories of biomass were not reported, the regional TPO dataset was used to impute harvest residue, mill residue, and other removals from the average historical relationship between these factors and removal rates of different classes of roundwood. These projections of hardwood and softwood harvest were broken down by type and distributed spatially based on the SRTS model outputs.

[9] The SRTS baseline estimates are a BAU case (they’re in the same range as historical yields) where the USFS projections are all optimistic.

2.1.3 Sustainable potential

Given the specific US SE context, the concerns already raised by different stakeholders with respect to pellet production, and the sustainability criteria in the EU Renewable Energy Directive (EU 2009) and other EC communications, two main impact categories have been considered in detail: biodiversity and carbon balances. In 2014, the EC decided not to propose binding sustainability criteria for solid bioenergy (EC 2014), indicating that those passed for liquid biofuels might apply to solid bioenergy. This led main pellet-importing countries to develop specific sustainability schemes for solid bioenergy (see e.g. Iriarte & Fritsche 2015).

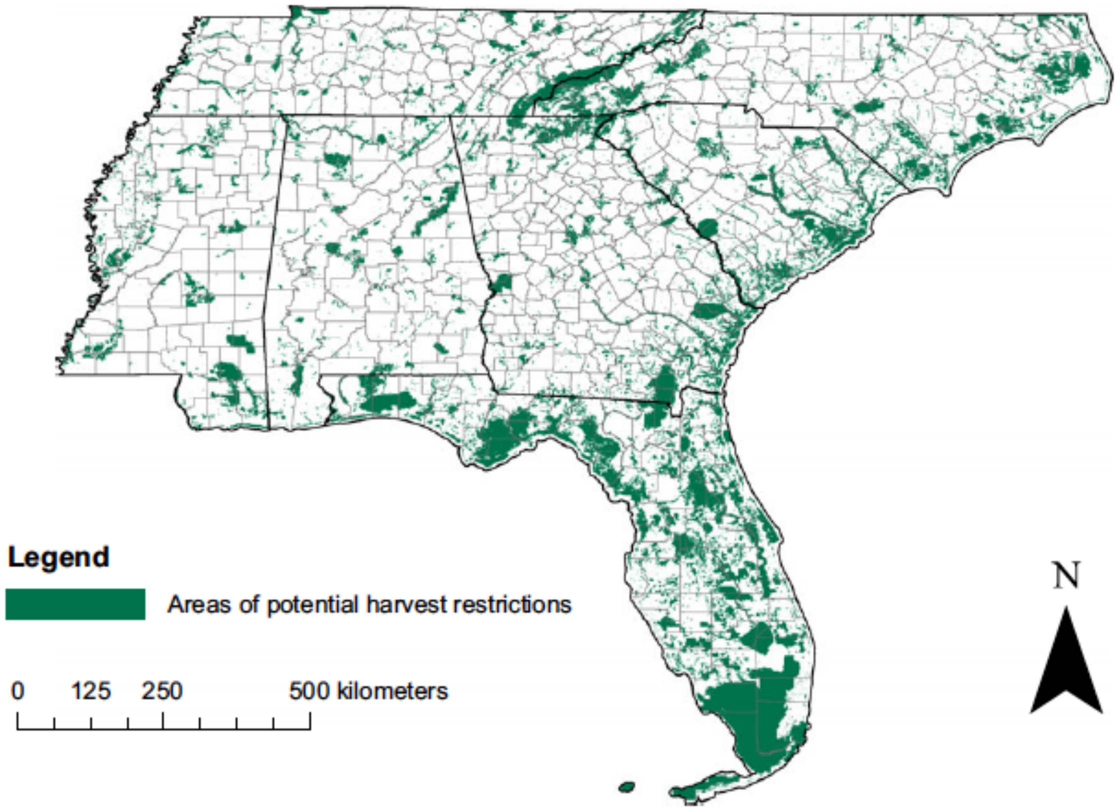
With respect to carbon balances, this report assumes that annual harvested volumes will continue to remain lower than annual forest increment. Regarding GHG emissions of forest bioenergy, we have followed the approach given in BioTrade 2020+ deliverable 2.4 (see Iriarte et al. 2016). We consider biomass combustion to be carbon neutral, yielding in most cases a net GHG emission savings when biomass pellets displace fossil fuels for electricity generation (see e.g. Giuntoli et al. 2014). Other concerns, such as carbon debt, have not been considered in this analysis. For this reason, life cycle GHG intensity is not considered a practical constraint on biomass sourcing from the US SE.

The key constraint employed in determining sustainable sourcing potential for this analysis is biodiversity conservation. Geospatial data allows the exclusion of biomass sourced from areas and habitat types of high biodiversity conservation value. We start from the county level gross technical potential, limiting these yields by application of the following three layers of constraints:

1. Protected areas, areas identified as having special conservation significance, private lands covered by conservation easements, or areas classified as wetlands or other water bodies. These sourcing restrictions were developed and presented in Galik & Abt (2015) (**Error! Reference source not found.**)
2. Other set-aside areas of special biodiversity concerns as per the rarity weighted richness index (NatureServe 2013) (**Error! Reference source not found.**)
3. A partial set aside based on forest types of the US SE. In particular, the exclusion of gum-cypress, and a 10% exclusion of oak-pine forest types (IINAS, EFI & JR 2014).

The first layer of exclusions was derived from an analysis similar to this one that sought to evaluate the sustainable biomass resource base for export from the US SE to the EU (Galik & Abt 2015). The authors excluded areas that are protected, have particular conservation significance, or are covered by conservation easements (see **Error! Reference source not found.**).

Figure 13: High conservation value, or otherwise protected areas.



Source: Galik & Abt (2015)

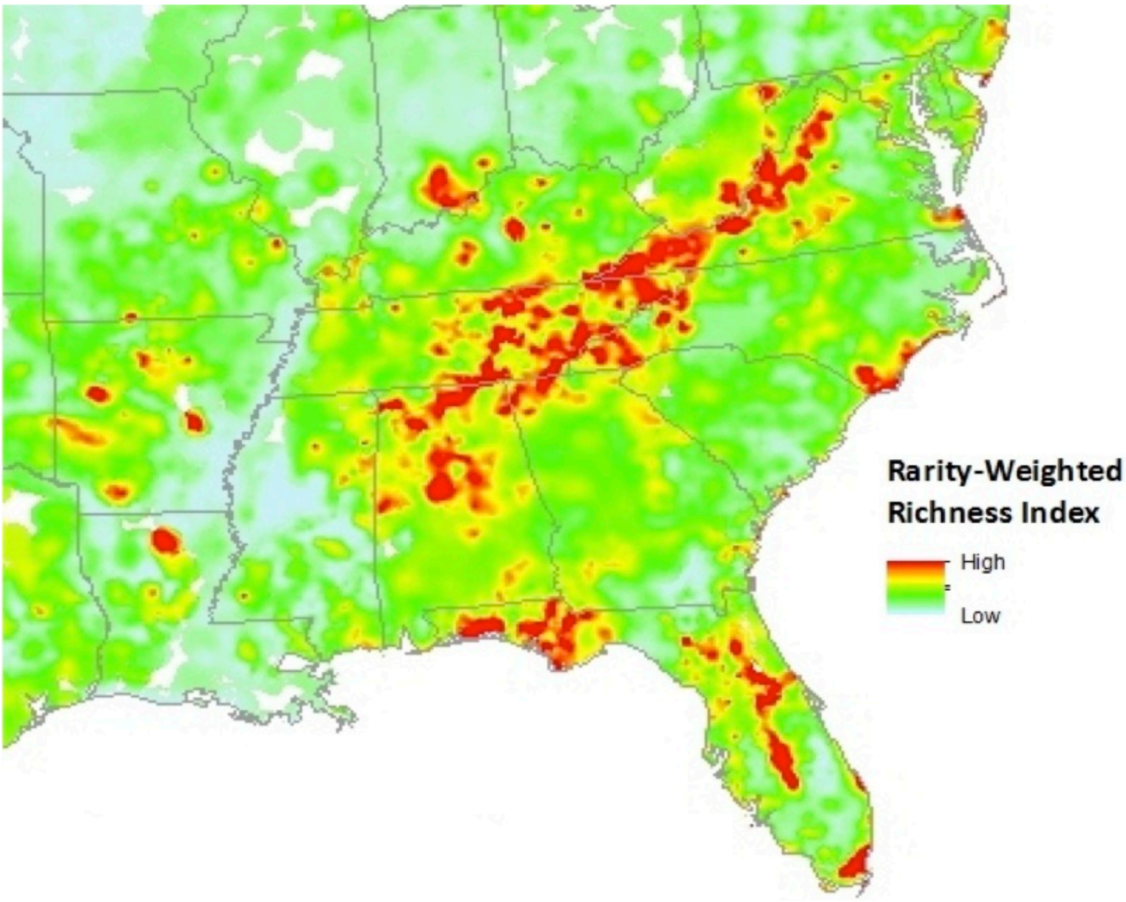
Note: Green areas are areas of high conservation value or protected areas.

While the approach taken by Galik & Abt (2015) provides a strong basis upon which to build our sustainability spatial constraints, we take a conservative approach to biodiversity conservation by employing additional spatial masks to further ensure the comprehensive exclusion of high biodiversity value areas.

In addition to the Galik & Abt constraints, we employ the rarity-weighted species richness index (NatureServe 2013; Albuquerque 2015), which scores locations based on a combination of species richness and the rarity of the species present (see **Error! Reference source not found.**).

Regions scoring high (>1) on this index were considered to be of high biodiversity conservation value and were therefore excluded.

Figure 14: Rarity-weighted species richness index aids in identification of diversity "hotspots" to screen out in evaluating sustainable potential



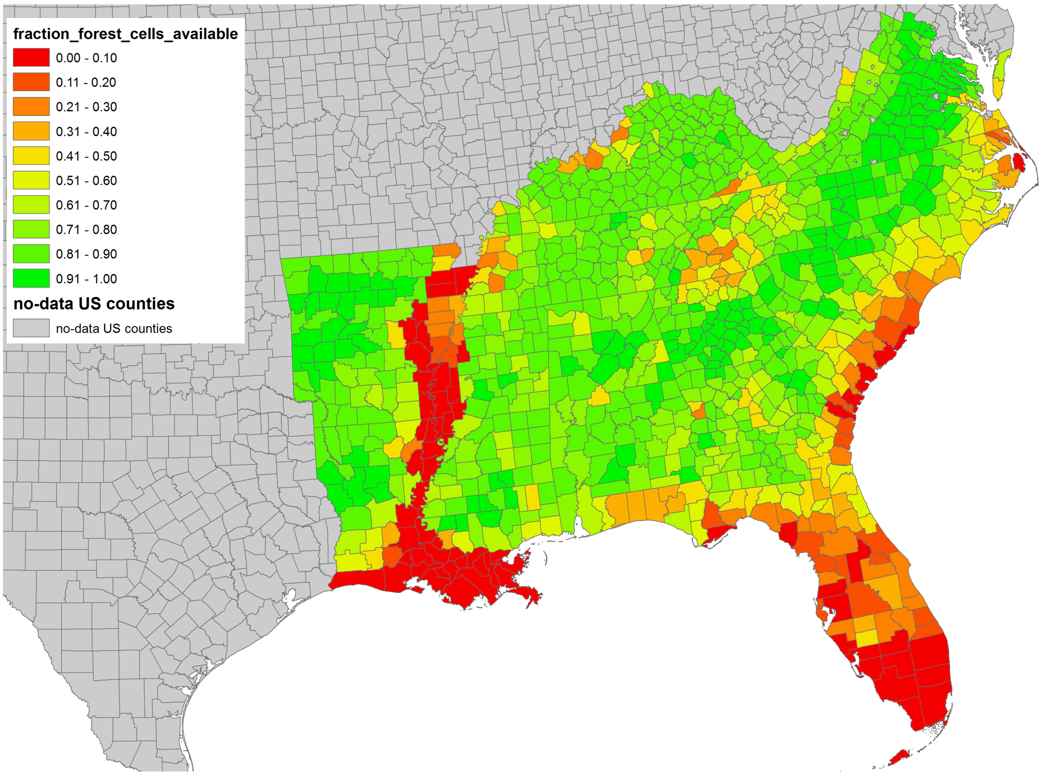
Source: NatureServe (2013)

Finally, certain high-conservation-priority forest types (see **Error! Reference source not found.** for forest type map) were excluded or constrained from direct harvest for biomass. Forest types excluded were gum-cypress and elm-ash-cottonwood. Recognizing that some oak/hickory and oak/pine forest area will also harbor biodiversity conservation value, we exclude 10% of these forest areas (per IINAS, EFI, & JR 2014).

The three spatial constraints mentioned above overlapped to a significant extent, but each also covered areas that were not otherwise excluded. By merging these three layers with a raster map of forested area, we are able to determine the fraction of each county's forested area to be excluded from production to ensure sustainability. This fraction per county was the 'sustainability constraint factor' and was multiplied by the technical potential to determine the sustainable potential per county.

Error! Reference source not found. presents the spatial distribution and extent of exclusion created by these 'sustainability constraint factors' across the US SE.

Figure 15: The 'sustainability constraint factor' or fraction of each county's forest area that remains available for wood production after sustainability criteria are applied spatially



Source: own elaboration

Note: While these figures are presented at a county-level resolution, they result from a high-level analysis that is unable to characterize all of the smaller-scale dynamics at play in the forest industry of a given locality. As such, these results should not be considered applicable for county-level analysis or planning, where a higher degree of local nuance is warranted.

As described above, the sustainable potential for a given county is determined using the following equation:

$$P_{sc} = P_{tc} * \mathrm{SCF}$$

Where:

P_s = Sustainable potential in county c

P_{tc} = Technical potential in county c

SCF = Sustainability Constraint Factor

The specifics of the way these sustainability constraints might be implemented has a significant impact on the scale of the sustainable resource base.

We approach this analysis considering two basic mechanisms for implementation.

1. Net technical potentials for export (i.e. after sourcing of domestic demand) are spatially constrained to avoid unsustainable impacts. This approach is referred to hereafter as the "export biomass constrained" (EBC) case.

   *(technical potential – domestic demand) * SCF*

2. Gross technical potentials are constrained to avoid unsustainable impacts, with domestic demand then drawn from the sustainable resource base. This approach is referred to hereafter as the "all biomass constrained" (ABC) case.

   *(technical potential * SCF) – domestic demand*

Figure 16: Two different approaches to evaluating the sustainability of domestic demand – choice of approach greatly impacts sustainable potential for export

Source: own elaboration from Mai-Moulin et al. (2015)

Note: ABC = all biomass constrained; EBC = export biomass constrained

The basic difference between these approaches is that the first (EBC) approach constrains *only the biomass being counted for pellet export* to those areas not creating risk of unsustainable impact. In the second (ABC) approach – the approach taken elsewhere in the BioTrade 2020+ study – sustainability criteria are applied to *all* biomass production for all applications in the region.

The first case is more "realistic;" while EU policymakers may well apply sustainability criteria to imported pellets, they could not extend these criteria to all biomass harvest in exporting countries. On the other hand, a regulation that only covers a small part of the market risks failing to influence overall environmental performance, creating a "leakage" effect, wherein sustainable biomass is sold into export markets without any actual shift in harvest practices across the landscape.

Given the realistic nature of the first approach in terms of what the EU can demand, but the more ambitious approach to sustainability implied by the second, we discuss both scenarios in this analysis.

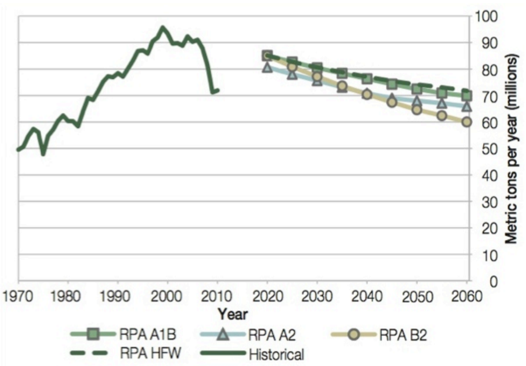
2.2 Determining potential surplus supply for export to the EU-28

2.2.1 US domestic biomass demand

Domestic demand data were drawn from Howard (2013). These values for roundwood equivalent production of various woody biomass products were then scaled based on FPM model projections of change in domestic demand for these materials. **Error! Reference source not found.Error! Reference source not found.** and **Error! Reference source not found.** present the FPM model projections from the 2010 RPA (Ince 2011; USFS 2012) for paper products and structural panels respectively. Among panels, only composites such as particleboard and oriented strand board (OSB) compete with energy for biomass.

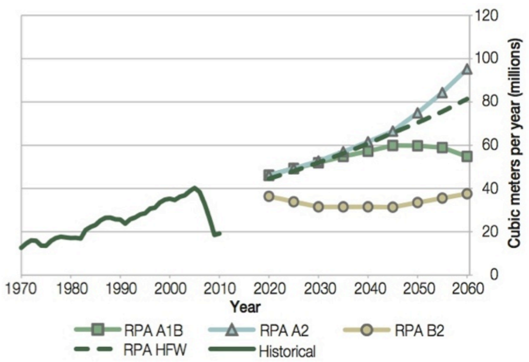
These materials have risen to about 60 percent of the total US panel market, and are projected to occupy 80 percent of the market by 2060 (Adair 2010). We therefore account for 60% of structural panel demand in 2015, 65% in 2020, and 70% in 2030.

Figure 17: Annual US paper and paperboard consumption and projections by RPA scenario



Source: USFS (2012)

Figure 18: Annual US panel consumption, and projections by RPA scenario



Source: USFS (2012)

The RPA scenarios used in this analysis project total future material demand nationwide. We allocate these projections to the SE region based on that region's share of total nationwide projected hardwood and softwood production. For example, the SE region is projected to produce 53.4% of the nation's softwood output in 2030, so it is "assigned" this fraction of the total demand for softwood material. We note that for demand projections uncertainty can be high. For example, in 2012 the RPA (USFS) projected continuing decline in paper and paperboard consumption, while most recent trends already show a moderate increase (UNECE-FAO 2015).

In projecting demand for conventional uses of biomass, this study uses the low-growth RPA B2 scenario for the BAU case and the more robust and renewable energy focused RPA A1B scenario for the High Trade case. More biomass could theoretically be available for export under a scenario of less robust GDP growth and biomass expansion, as these would reduce demand for biomass for conventional and energy uses. However, such a scenario cannot realistically be expected to coincide with high levels of biomass supply, so the high trade case uses the higher growth scenario to project domestic demand.

This study breaks from the strict RPA/SRES scenarios in its treatment of US domestic bioenergy demand, however, because the RPA projections range widely, and are driven in large part by the exogenous factor of domestic bioenergy policy. For example, the highest RPA scenario projection shows almost 2 billion tons of biomass used for energy in the US in 2060. This would require an overhaul of US forestry and energy sectors and would clearly not leave material for export to European markets.

There is no empirical basis upon which to vary the US biomass demand between BAU and High Trade cases. Moreover, while the High Trade case would call for low domestic biomass demand to enable higher exports, it is not reasonable to project a large increase in the use of biomass energy in Europe while holding US bioenergy use static. For this reason, we used the moderate domestic biomass demand growth projection from the RPA for both the BAU and High Export scenarios. The demand for domestic biomass for energy presented in this scenario is roughly consistent with the projected doubling of US biomass energy production by 2030 in the 2010 Annual Energy Outlook reference case (USDOE EIA 2010).

2.3 Scenario overview

This analysis considers two main scenarios that aim to capture different circumstances of the main parameters affecting the sustainable surplus of biomass for exports. These refer to BAU and the high trade cases. Table 4 summarizes key differences between these two scenarios.

Table 4: Main parameters defining the BAU and High Trade scenarios

<table>
<tr><th colspan="2">Parameter</th><th>Business as Usual</th><th>High Trade</th></tr>
<tr><td rowspan="2">Technical potential</td><td>Harvest residues extraction rate</td><td>50 %</td><td>67 %</td></tr>
<tr><td>“Other removals” extraction rate</td><td colspan="2">50%</td></tr>
<tr><td>Sustainable Potential</td><td>Biodiversity conservation</td><td colspan="2">Spatial exclusion of sourcing as described in section 2.1.3</td></tr>
<tr><td rowspan="2">Domestic demand</td><td>Domestic demand for pulp and panel feedstocks</td><td>RPA Projection B2</td><td>RPA Projection A1B</td></tr>
<tr><td>Domestic demand for biomass for energy</td><td colspan="2">RPA Projection B2</td></tr>
</table>

Source: own elaboration

Complementary to the scenario approach, we analyze the importance of where in the supply chain sustainability criteria are applied. We consider a conservative model where all biomass is required to comply with the biodiversity constrains (ABC approach) as well as one in which only exported biomass is constrained by the biodiversity criteria (EBC approach). Section 2.1.3 presents a detailed explanation of these cases.

2.4 Biomass cost curve development

In evaluating the potential supply of biomass from the US Southeast to the EU, the cost of mobilizing this material and bringing it to market is a key consideration. While not including cost or supply chain capacity as constraints, this study does evaluate the overall cost of delivering pelletized woody biomass to the Amsterdam-Rotterdam-Antwerp (ARA) port region. To estimate the cost of biomass pellets as delivered, the following cost components are included:

$$C_D = C_f + C_{Pt} + C_{Tdf} + C_{Tdp} + C_{Ti} + C_H$$

Where:

C_D = Total cost of biomass pellets delivered to ARA

C_f = Cost of feedstock collection/purchase/chipping

C_{Pt} = Cost of pre-treatment

C_{Tdf} = Cost of domestic transport from field to pellet plant

C_{Tdp} = Cost of domestic transport from pellet plant to export location

C_{Ti} = Cost of international transport from export location to ARA ports

C_H = Cost of handling

We use cost estimates from the Billion Ton Update (Perlack at al. 2011) for biomass cost at the roadside. The residue biomass considered here is derived from the logging residues (LOGR) category in the Billion Ton Update. Cost characteristics for the “other removals” category in our analysis were derived from the “simulated thinnings” (LOGT) case. While Perlack et al. also report values for what they call “other removal residues” (LOGO), this category of biomass is specific to land conversion from forest. While both thinnings and land conversion removals are included in the TPO database under the “other removals” heading, we limit our analysis to only 50% of reported/projected “other removals” in order to constrain the biomass considered to thinnings and other non-harvest activities while excluding land clearing. In the case of thinning and residues, these costs include hauling to roadside and chipping.

The costs for the pulpwood fraction of the biomass material are based on the Billion Ton Update projected roadside costs for pulpwood timber. For harvest residues, the BTU assumes that the residue is removed as part of a whole-tree harvesting system wherein the tree is broken down at the roadside, meaning that the only costs are stumpage and the chipping cost. For thinnings, costs include stumpage, harvest, transport to roadside, and chipping. Costs associated with harvesting the material and extracting it to the roadside costs are estimated using the Fuel Reduction Cost Simulator (FRCS) model (Dykstra at al. 2009).

For privately-held timberland, the stumpage price assumed for thinnings and residues reflects the opportunity cost of selling into the biomass energy market. Where total utilization of these materials is low, a nominal price of $4/dry short ton applies to the material. As more of the slash material is mobilized, its price rises steadily up to 90% of pulpwood cost, as its demand drives up the price and the pellet market eventually begins to compete with the pulp and panel markets.

The Billion Ton Update reports biomass production costs in increments of $10. This is in fact the marginal cost of mobilization (i.e. price of the last ton) in each $10 increment rather than the actual cost of delivery of each tonne of material. We use this BTU cost data to determine the fraction of each category of biomass able to be delivered at each $10 increment up to $200/short ton (at which price it is assumed that all bioenergy feedstock material can be mobilized).

We calculate these fractions at the statewide level even though estimates are available at the county scale because the Perlack et al. study contains the caveat that "due to sampling constraints, forestry data are not intended for use at the single-county level." We apply the calculated state-level cost fractions to our own county-level output projections to derive cost curves for mobilization of the biomass material in our projections.

Pre-treatment and pelletization, and handling costs are derived from Ehrig et al. (2014) and Pirraglia at al. (2010). These cost calculations take into account amortized capital expenditures, financing, handling, energy cost, as well as both fixed and variable operation and maintenance costs. Operational characteristics of the facility and feedstock characteristics are also taken into account.

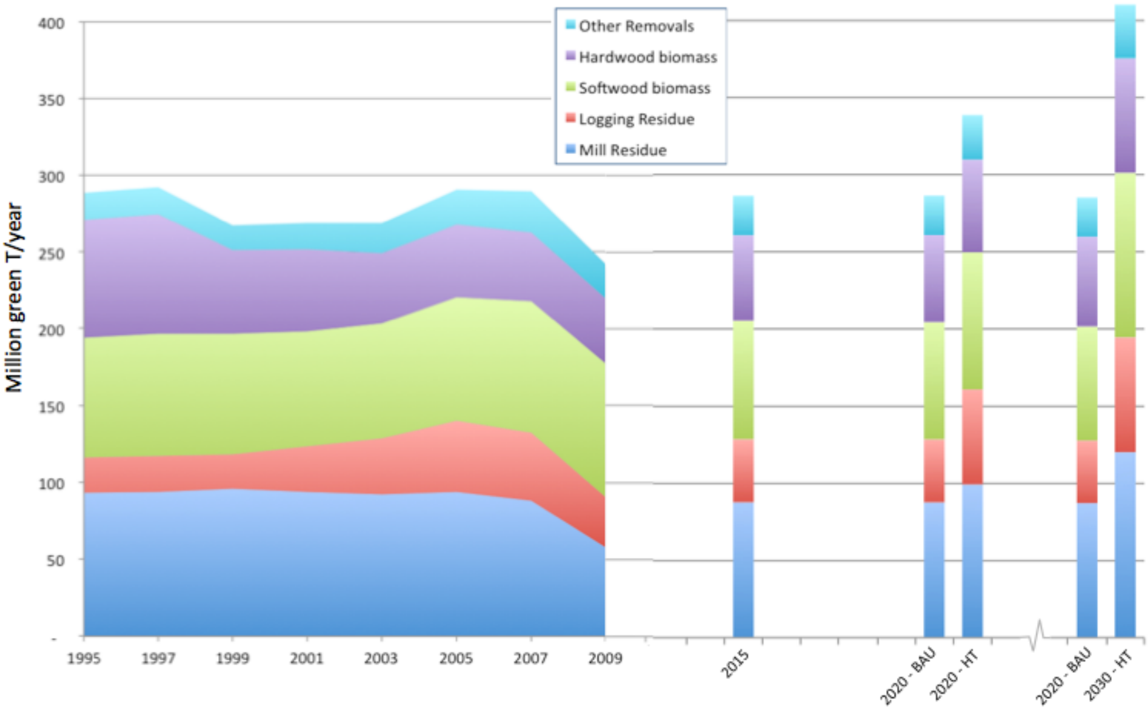
Given the large amount of material considered here, and the large infrastructure that would be required to achieve this scale of biomass export, pelletization is assumed to occur in large (120,000 T/year) facilities. Transport costs are applied to products from each county on the basis of the distance travelled from that county's centroid point to the port of export and then shipping cost to the Amsterdam/Rotterdam/ Antwerp port region.

3 Results

3.1 Technical and Sustainable biomass potential

The base projections for this analysis are the technical potentials, or the amount of key biomass types that could technically be mobilized from the US SE region going forward. **Error! Reference source not found.** presents the historical data on yields of these types of biomass as well as the projected 2015 yields and both business as usual (BAU) and "high trade" scenarios for future technical potential. These projections are broken down by biomass type into both hardwood and softwood pulplogs and miscellaneous removals, as well as the "other removals" biomass class, logging residues, and mill residue.

Figure 19: Historical and projected future total biomass availability



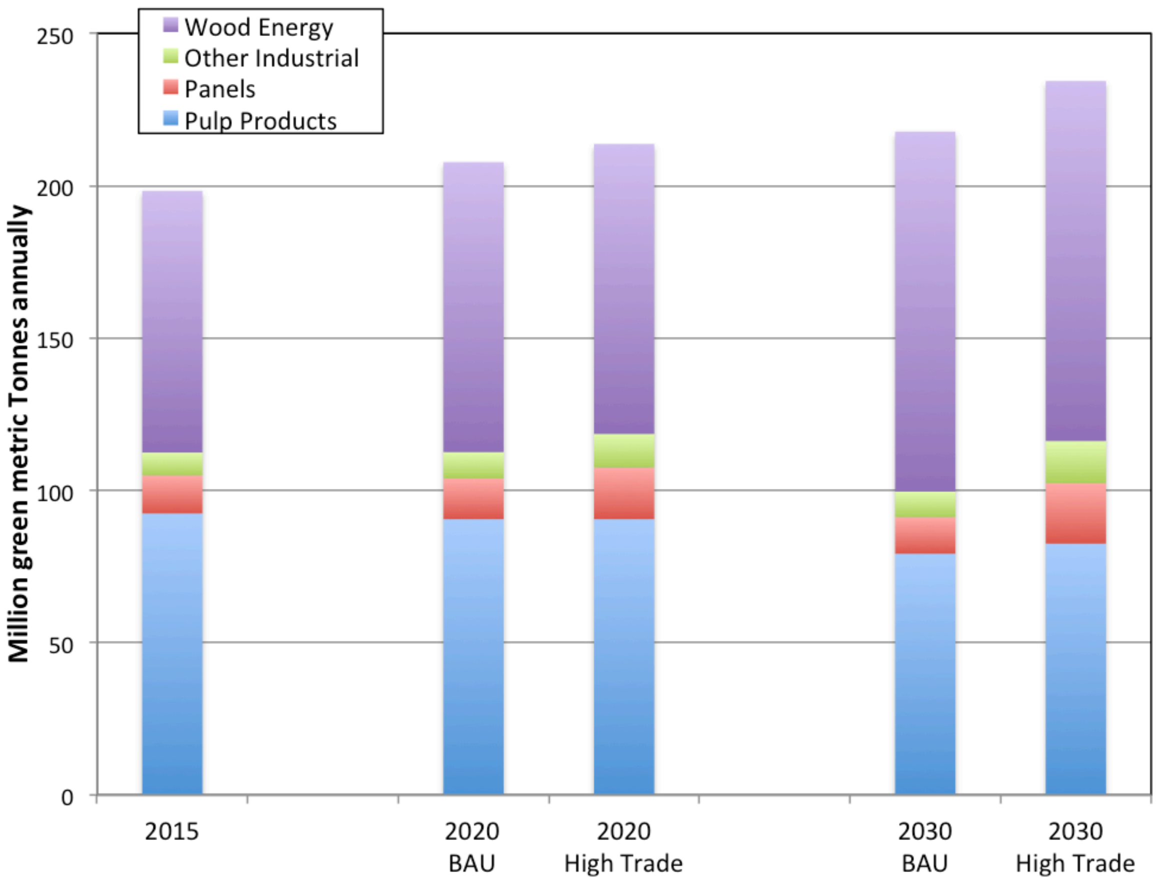
Source: own elaboration

Note: Per the TPO database convention, the pulpwood, composite products, fuelwood, and miscellaneous categories are grouped together, and are here referred to simply as "biomass."

The technical potentials reported above are *total* yields per year of the types of material that could be suitable for pelletization and export. Excluded from these values are harvest volume of sawlogs and veneer logs, as these higher-value materials are unlikely to be utilized as bioenergy feedstock. Further excluded are the 33-50% of harvest residue that is left in the field in the technical potential case as well as the 50% of the "other removals" category of biomass that is held back in order to avoid counting material removed through land clearing operations.

Furthermore, the biomass harvest potentials presented in **Error! Reference source not found.** are gross availability without accounting for domestic demand. **Error! Reference source not found.** presents domestic demand for the categories of biomass utilized in the pellet market. This analysis assumes that these domestic demands for material are satisfied before biomass can be made available for pelletization and export.

Figure 20: Projected domestic demand for biomass from the US SE region for key sectors competing with the export pellet market for biomass material.



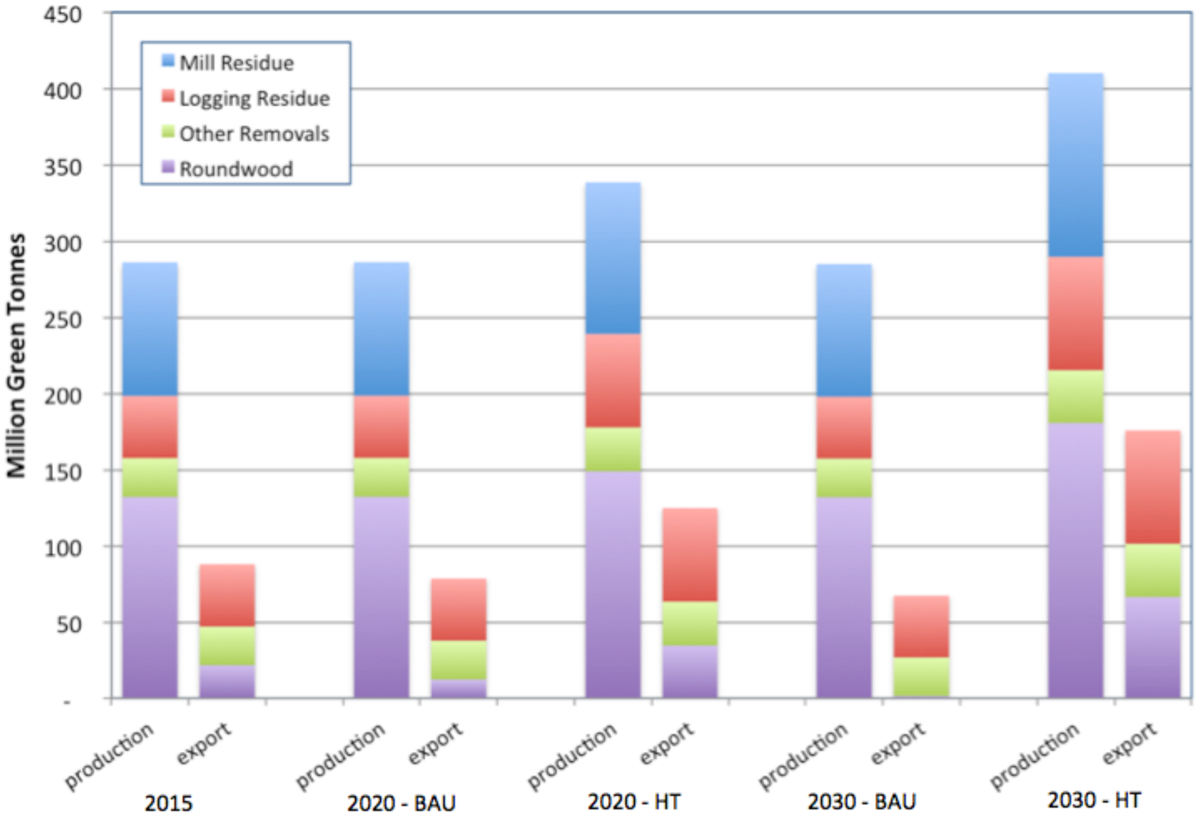
Source: own elaboration drawing on Forest Products Module outputs (Ince 2011)

Note: Wood energy demand considered here includes traditional wood energy use for heat as well as "modern" bioenergy.

Combining projected production potential with projected domestic demand, we arrive at estimates of technical export potential. **Error! Reference source not found.** presents the technical potential projected for the cases under investigation as well as the material theoretically available for export after domestic demand has been met. It should be noted that these are theoretical export values, unconstrained by pelletization capacity or cost.

Furthermore, these are export capacities, rather than EU import capacities. If this material were mobilized and made available for export, EU imports would be in competition with demand for biomass for various uses in third countries. The global market for these resources is not evaluated here; all export potential from the US SE is considered available to EU markets.

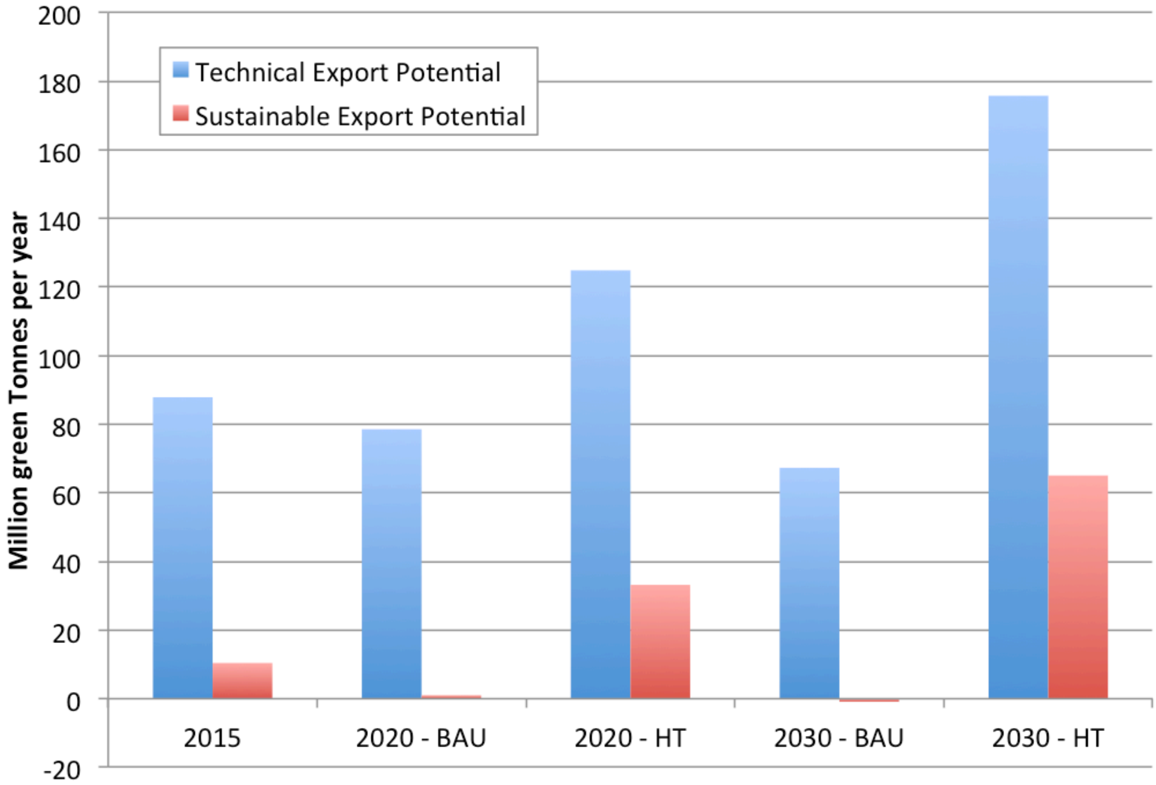
Figure 21: Projections of total technical production potential from the SE USA forests, (for all uses of biomass), and potential available for export once domestic demand is met.



Source: own elaboration

In order to determine the sustainable potential for export, we constrain the technical potentials reported in **Error! Reference source not found.** based on spatially discrete impact and forest type data. **Error! Reference source not found.** below displays both technical and sustainable potential of biomass for export. Presented here are our conservative sustainable potential values – derived from the "all biomass constrained" approach. In some projections, the sustainable export potential in this case is found to be negative, implying that domestic demand for biomass from the region is expected to be greater than total sustainable biomass production.

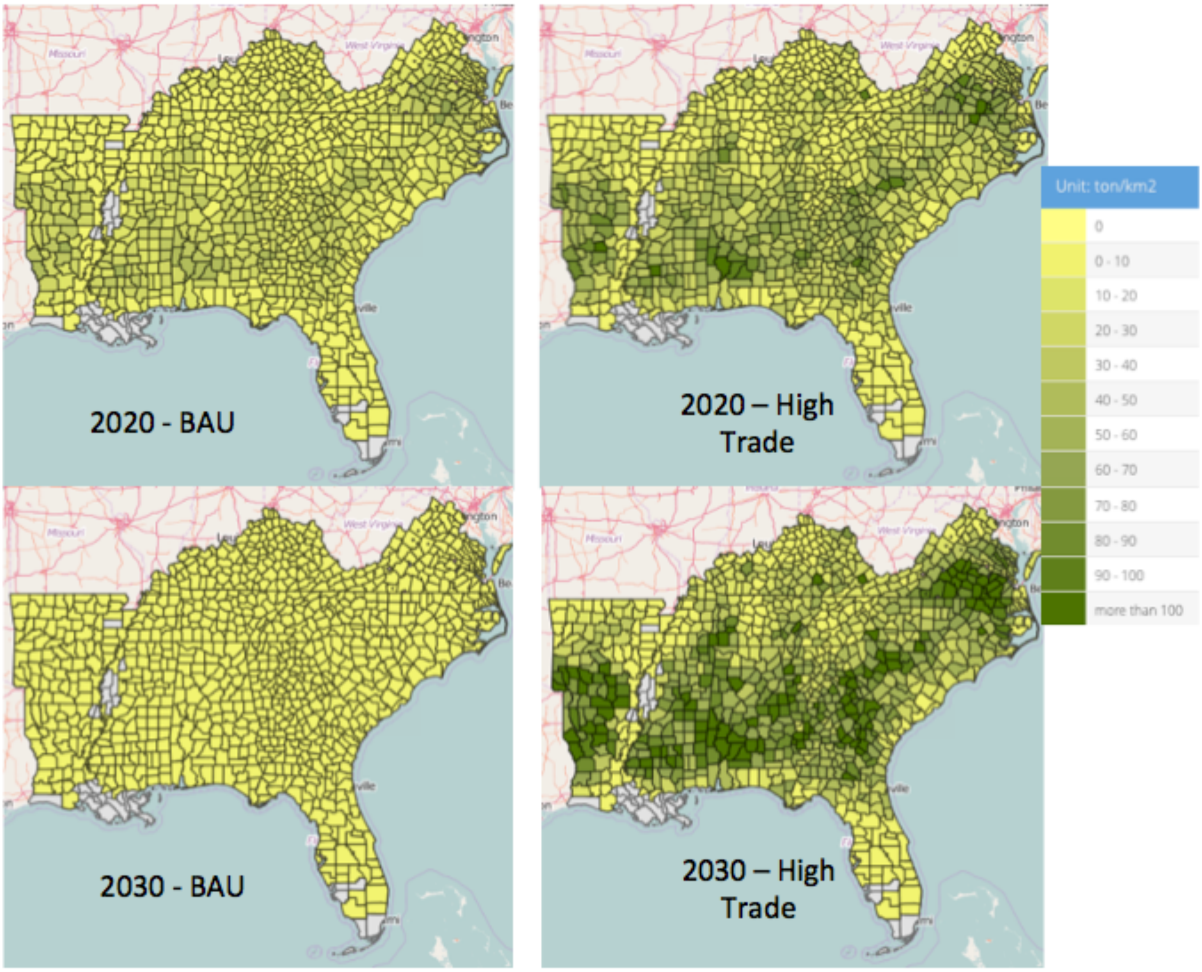
Figure 22: Technical export potential (same as export bars in fig 20) and sustainable export potential when all biomass harvest is confined to sustainable sourcing



Source: own elaboration

The US SE is a very large geographical area, and this analysis projects material availability at a county-level spatial resolution in order to derive more accurate cost estimates as well as to enable the sustainability constraint analysis, which is inherently spatial in nature in that it seeks to exclude certain categories of forest. **Error! Reference source not found.** shows the projected biomass availability in the 2030 high trade case at the county-level resolution.

Figure 23: Spatial distribution of net sustainable potential for roundwood in the 2020 and 2030 BAU and High Trade cases



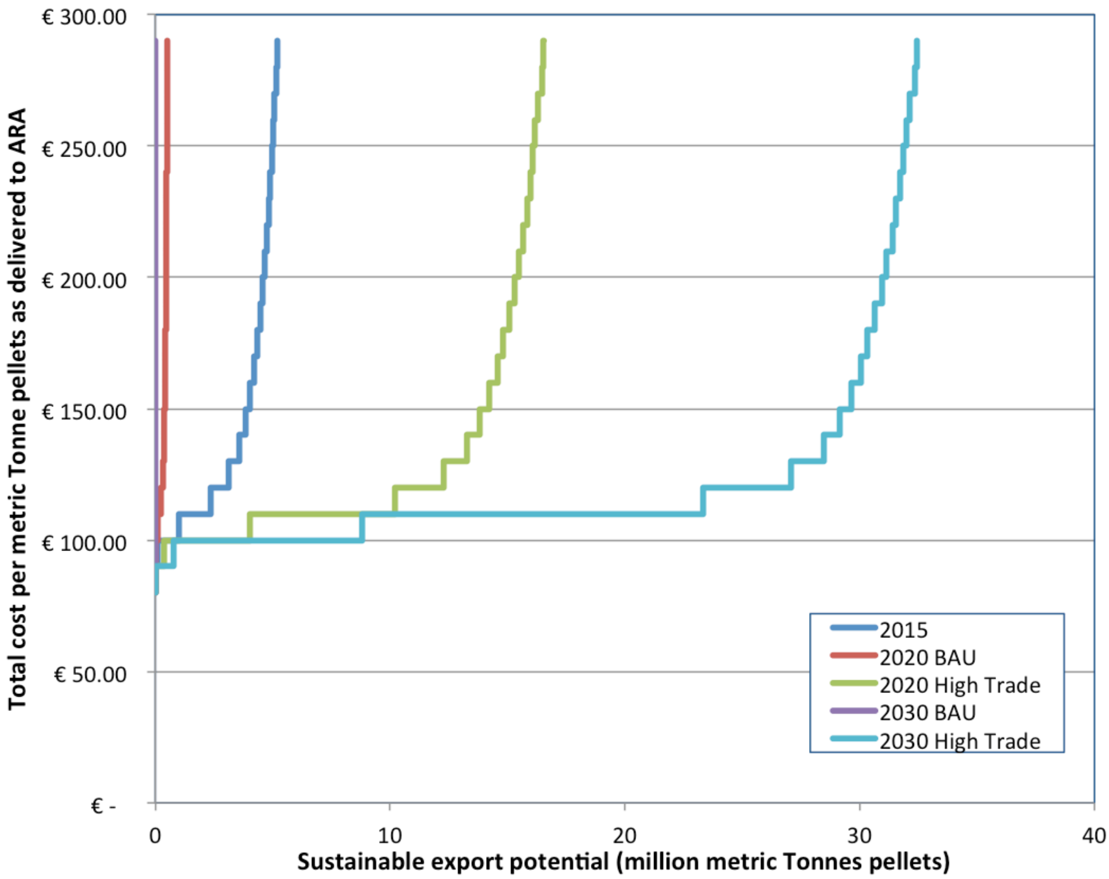
Source: Biotrade 2020+ project (http://s2biom-test.alterra.wur.nl/web/guest/usa)

Note: While these figures are presented at a county-level resolution, they result from a high-level analysis that is unable to characterize all of the smaller-scale dynamics of variations at play in the forest industry of a given locality. As such, these results should not be considered applicable for county-level analysis or planning, where a higher degree of local nuance is warranted.

3.2 Biomass supply costs and cost-supply curves

Mobilisation of biomass from the field can be a costly proposition, and the cost of producing this material is perhaps the most critical component of the feasibility of biomass energy as a meaningful component of a low-GHG energy future. **Error! Reference source not found.Error! Reference source not found.** presents cost curves for delivery of technically available biomass (i.e. the technical potential) as biomass pellets to the Amsterdam-Rotterdam-Antwerp port region. The steepness of these curves is attributable to the modeled cost of the biomass feedstock drawn from Perlack et al (2011). Most of the material present in these sustainable export curves is logging residue and thinnings that the USFS considers to be low cost/value materials for the most part, with a limited amount harder-to-access material become available at higher mobilization costs. As described in the methods section, the transport costs are averages on a state level. To determine more accurate cost of supply would require detailed analysis of the situation in each county including possible locations of pellet mills and local logistics, which would have gone beyond the frame of this work. The cost levels should therefore be considered as indicative.

Figure 24: Biomass cost curves for sustainable export potential - 2015, 2020, and 2030, BAU and High Trade scenarios.



Source: own elaboration

Note: The 2030 BAU curve is not visible as there is no excess material available for export in that projection. For comparison, in 2015, prices CIF ARA ranged between 160-180 Euro/tonne. Presented here are cost curves and so do not include profit taking at various points in the supply chain that would be reflected in these market prices.

4 Discussion

4.1 Technical biomass potential

This analysis makes it clear that there are significant quantities of biomass that could be mobilized from the Southeastern US for use in the bioenergy markets of the EU. However, the feedstock quantities indicated for some cases in the results above are significantly higher than the 6.9 million tonnes of pellets that are estimated to have been produced *nationwide* in 2014 (UNECE-FAO 2015). This is due to the fact that these are total biomass potentials, unconstrained by pelletization or supply chain capacity. It is worth noting that a pellet industry can only flourish if the traditional (especially sawmilling) industry flourishes, given the interlinkages between these industries (Wear and Greis 2013). The pellet industry is expected to expand significantly if these traditional uses of biomass flourish, since this would lead to low quality logs and residues becoming available. Again, however, these dynamics are not explicitly accounted for in the present analysis.

Other studies have analyzed the amount of forest biomass for bioenergy in North American forests. For example, a report produced for DECC in the UK estimated that by 2020, there could be up to 47 million oven dry tonnes (odt) per year of US forest harvest residues available, that would otherwise be burned at the roadside, as well as another 17.5 million odt/year of residues from fire treatment of US forests (Stephenson & MacKay 2014). It should be noted that their estimates are in oven dry tonnes, where the estimates contained in this report are in green tonnes, which are assumed to be about 50% water.

4.2 Sustainable biomass potential

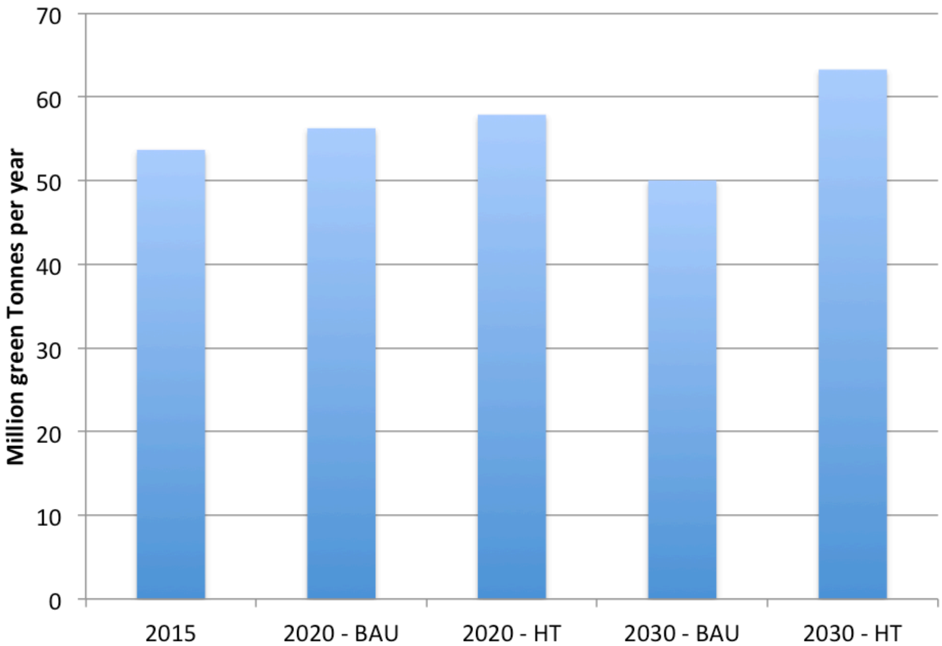
As described above, the sustainable potentials presented in **Error! Reference source not found.** assume that *all biomass harvesting* in the US SE is confined to those areas deemed to meet the sustainability criteria considered here. For this reason, these are conservative estimates of availability, and in some cases the sustainable export values are very small or even negative. Negative export potential implies that domestic demand for biomass from the region is expected to be greater than total sustainable biomass availability. This could therefore require net import of biomass, shifting of production out of the Southeast region, greater harvest level in sustainable regions, or some unsustainable harvest in order to meet domestic demand.

The biodiversity conservation scheme considered here is ambitious, and if applied across all forestry activities would leave very little remaining scope for export. However, these estimates are drawn from actual harvest projections, which in most cases are significantly lower than the total net annual increment of biomass growth in the forest (USFS, 2012). This means that there is often some additional biomass that could be harvested from sustainably managed forests if demand were sufficient.

It should be noted that any sustainability criteria the EC (or EU member countries) could impose on the use of biomass under its Renewable Energy Directive and related regulations would only apply to the material actually used in Member States. This means that while the approach presented here gives our best estimate of the amount of actually sustainable material that could be available for export from the US SE, it does not reflect the realities of the policy frameworks that might cause that material to be used. A much more likely framework would constrain sourcing in the US Southeast only for the bioenergy feedstock material destined for use in the EU. This approach creates the risk of leakage, wherein the products of unsustainable activities are simply shifted from the export biomass market into other sectors rather than being prevented altogether.

By comparing the sustainable potential under the "all biomass constrained" case against the nominally sustainable potential if only export biomass were constrained we are able to estimate the scale of the potential leakage that could be driven by such an approach. **Error! Reference source not found.** presents the scale of this leakage risk for each of our study cases.

Figure 25: Leakage risk from only applying sustainability constraints to exported biomass



Source: own elaboration

As is made clear in **Error! Reference source not found.**, there is real risk of leakage from a policy constraining only exported pellets for sustainability. This should not be taken as an argument against applying sustainability criteria to EU pellet imports, but as indication of the limited efficacy of such a policy alone. The US SE is a key producer of pulp & paper and timber products, for which no export criteria other than the EU Timber Regulation apply.

A more comprehensive strategy, applying sustainability criteria to all imported biomass products as well as advocating for stronger protections within the United States, would go farther than a bioenergy-only policy towards meaningful biodiversity protections.

4.3 US Domestic Demand

The base case in the US Department of Energy's 2014 Annual Energy Outlook (AEO) projects a 10% increase in wood energy use by 2030 – a significant downward revision from a year earlier when the AEO projected an increase of 47% by 2030 (USDOE 2015). The bioelectricity industry is very reliant on policies such as technology-specific carve-outs in Renewable Portfolio Standards. These policies are in flux at present, in part owing to the uncertainty surrounding accounting for biogenic carbon emissions. This policy uncertainty has been combined in recent years with low natural gas prices due to the advent of hydraulic fracturing and the current shale gas boom in the US. Together, these factors have had a chilling effect on the recent growth of the bioelectricity industry and make its large-scale growth in the immediate future unlikely.

It could be argued that this slowing in demand for biomass energy in the US is a positive development from the perspective of the availability of that biomass for export to Europe. However, the pelletization capacity needs to be built, and a robust domestic demand as well as active incentives from the US government would stimulate the necessary investment. Also, the lack of robust demand growth in the US stems at least in part from factors that would be equally true for the EU export market. This includes the economic and engineering challenges of utilizing biomass residue for energy and the mixed reputation of bioenergy among environmental NGOs. The latter of these issues is being felt acutely in Europe already.

Also, demand in the EU remains uncertain. The Dutch Parliament recently voted to suspend an on-going biomass support scheme aimed at increasing the co-firing of wood pellets in existing coal power plants to 3.5 million tonnes per year by 2020 (Upton 2016). Even before this action, however, use of pellets in the country had dropped to near zero, due in part to uncertainties surrounding the sustainability of the fuel and how any EU policy to manage sustainability will be implemented (UNECE-FAO 2015).

4.4 Methodological limitations and sources of uncertainty

The key primary uncertainty surrounding this and any projection analysis is the fact that subjective methodological decisions can have a large impact on the ultimate result. An investigation of the sensitivities in this work shows that choice of RPA scenario, residue removal level, ABC vs EBC policy framework, and mixed oak woodland utilization rate for sustainability masking are the four largest variables in driving our results.

Furthermore, many of the drivers of this model are themselves sensitive to both domestic and global policy and economic circumstances, which are prone to unanticipated changes. Factors such as the composition of housing stock into the coming decades, the forward trends in pulp and paper use, and the hard-to-predict effect of insect infestations can have a large impact on the availability of biomass for pelletization and export. Furthermore, there is uncertainty as to the extent to which non-industrial private forest owners will be willing to harvest biomass for bioenergy on their property (e.g. Aguilar, Cai & D'Amato 2014; Galik

2015). The scenario approach described here aims to manage this variability and uncertainty by presenting a broad range of outcomes across many possible futures.

The global market for pellets or other products demanding the same biomass resources is not considered here. If the resource base described in this report were mobilized from the US SE region and were available for export, the EU would be competing economically for this material. It is possible that EU member states would be the primary importers of this biomass, but the potentials reported here should be considered as export potentials from the US SE and not necessarily as import potentials for the EU. However, given that the only other major market for imported wood pellets is in East Asia (Korea and Japan, which are supplied by exports from other countries in the region and Western Canada), it is likely that EU member states will remain the largest import market for US biomass in the coming years.

Our results, and most other ambitious projections of the availability of biomass for bioenergy, view harvest residues and thinnings as a particularly large, and largely untapped, resource base. However, forest residues have a high concentration of bark (because of their high surface to volume ratio) as well as soil and other debris. These materials can cause slagging, fouling and corrosion in boilers (Stephenson & MacKay 2014), and are therefore not a preferred fuel. There remains some uncertainty as to the extent to which these materials will be able to be made useful as bioenergy feedstocks.

5 Outlook on future work

The results presented in this report raise new and important questions that will require further research.

1. As discussed above, this analysis evaluates the amount of biomass material *available* under several scenarios but does not consider the supply chain (including pelletization) capacity considerations that could constrain its availability to energy markets. Combining these estimates with supply chain capacity projections would enable more complete techno-economic projections of pellet availability.
2. Further research is needed to determine the extent to which the quality of some residues (e.g. logging residues and thinnings with high content of bark) will constrain the mobilization and use of the harvest and thinning residue materials that this analysis shows are critical to sustainable export of biomass for energy from the US SE. Research is also needed to develop harvest and post-harvest treatment practices to enable further utilization of these material types.
3. This type of availability analysis will need to be merged with a sophisticated understanding of global biomass markets in order to better understand the role of other players in the global market, both in the pellet sector as well as in other sectors demanding the same feedstocks. This will help determine the extent to which the sustainable export potentials described here will be available for import to the EU.
4. A better understanding of non-industrial private forest owner´s willingness to harvest biomass for bioenergy is needed to estimate "mobilizable" sustainable potentials.
5. Further investigation could create a better understanding of the interplay between composition of housing stock into the coming decades, the forward trends in pulp and paper use, and the hard-to-predict effect of insect infestations as well as the sensitivity of the outcomes to each factor.
6. If sustainability criteria were to be applied to EU imports of biomass pellets, this would be unlikely to significantly impact activities on the ground in the US SE region unless these criteria were applied across the whole of the US forest industry (an outcome that the EC could not control). A better understanding of the dynamics of this so-called "leakage" in the forest industry could help the EC determine the best framework for ensuring the sustainability of its imports in an effective manner.

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6 Appendix A – Greenhouse gas supply curves

As described in section 1.4 the main body of this report, most life cycle assessment studies show some greenhouse gas reductions from displacing EU grid electricity with bioelectricity from US pellets. These findings are in line with the life cycle emissions calculated in the EC's own research conducted by its Joint Research Centre (Guintoli et al. 2015). These analyses typically consider combustion of biogenic fuels to be carbon neutral – an approach that has been controversial in some quarters. However, following the current approach of the EC, we assume carbon neutrality for biomass combustion in this report. We also assume that annual harvested volumes will continue to remain lower than annual forest increment. Other concerns, such as carbon debt, have not been considered in this analysis.

For the reasons described above, we have not considered life cycle GHG intensity to be a meaningful sustainability constraint from an EU policy perspective. However, because carbon intensity remains an important environmental characteristic of energy systems, and in keeping with the other BioTrade 2020+ case studies, we have evaluated the life cycle GHG footprint of the biomass pellets considered in this analysis. GHG emissions are calculated across the entire supply chain, taking into account all of the following emission sources:

- Cultivation and harvesting activities
- Fertilizer production to replace nutrients withdrawn by residues removal
- Pre-treatment and pelletization facility operations
- Domestic and intercontinental transport

Greenhouse gas emissions are calculated based on the same characteristics of the pellet production cost. GHG emissions of transport are, just as the cost, taken from the BIT-UU model. EU default values are used for the emissions associated with cultivation, harvesting and pre-treatment. Further detail on the Life Cycle GHG intensity analysis can be found in BioTrade 2020+ deliverable 2.4 (Iriarte et al. 2016). Figure 26, below, presents the GHG intensity curves for the potential supply estimated in this analysis.

Figure 26: Aggregate greenhouse gas supply curve for potentials estimated in this analysis