Implications of Legislative Woody Biomass Definitions

January 2011

Conducted by:

Larson & McGowin Inc
Mobile, AL
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Commissioned by:

Southeast Agriculture & Forestry Energy
Resources Alliance – Research Triangle, NC
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Principal Investigators:

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Executive Summary

Introduction

Current state, national and international legislation are encouraging development of renewable sources of energy for both energy security and climate change issues. Central to these policies and legislation is the development of energy standards such as renewable portfolio standards (RPS) for electricity and renewable fuel standards (RFS) for fuel.

Development of such comprehensive energy standards include discussions on:

- Which energy sources qualify as renewable;
- How certain feedstocks are procured;
- The appropriate allocation or limit of each feedstock within the standards; and
- Whether to implement national or state standards.

Of special interest in the South is the inclusion of woody biomass as a viable feedstock because of the abundance of wood resources and a readily available procurement infrastructure.

The debate on the inclusion of woody biomass as a renewable energy feedstock has centered on:

- The types of forestry products that are eligible (i.e., logging residue vs. standing timber); and
- The types of stands from which it is harvested (i.e. planted vs. natural)
- The types of timber materials that are harvested (i.e. premerchantable vs. merchantable).

Much of this debate is driven by concern from existing commercial forest products consumers in regard to raw timber supply competition and price pressure, as well as concern among environmental NGOs of widespread land use changes throughout the South.

Finally, because the majority of woody biomass is owned by private landowners, for any energy standard to be effective, it must take into consideration how woody biomass is grown, harvested and sold in the South and the available supply.

Study Objective

This study was commissioned in order to analyze the impact of woody biomass definitions on the South's ability to meet a renewable electricity standard. Various biomass definitions were identified and compared for both current and proposed energy legislation. Each of these definitions was examined as to how they relate to woody biomass. Estimates of current woody biomass supply were then derived based on the various biomass definition categories, characteristics of the Southern timber resource, and proposed energy consumption levels. Additionally, future availability and supply estimates were modeled for additional analysis of sustainability. Finally, the results of the study were examined in order to assess the potential of the RPS/RES attainment levels from wood for the South as a whole, as well as individual states.

Summary of Key Findings

1. Numerous and contradictory definitions of woody biomass exist in current and proposed energy legislation and policy directives. These definitions are vague and at times inconsistent with the way in which traditional timber products are grown, harvested and sold.

2. Of the total woody biomass in the South, 39% is an underutilized product type (i.e. salvage, plant residues, slash & brush, and logging residues), 58% is merchantable timber (i.e. pulpwood and small diameter trees) and the remaining 3% is in stands over 80 years old.

3. When restricting the total woody biomass in the South by current availability (what is not already being harvested for commercial wood products) and utilization rates (what is technologically and economically feasible to remove), the total woody biomass resource feedstock available for biopower is limited to 28%.

4. Restricting the potential woody biomass feedstocks depending on the type of stands where they grow and how they are harvested reduces the available amount even further. For example, by restricting the use of potential biomass to existing artificially regenerated stands only and disallowing premerchantable harvesting, the total woody biomass feedstock available falls to only 6.81%.

5. For the South overall, only 1% of the total unrestricted woody biomass feedstock supply would be needed to generate 5% of our electricity when calculated based on current energy sales and 40% plant efficiency/LLH heat input.

6. This 1% supply level is consistent across most of the individual Southern States with the exceptions of those that have higher electricity demand and lower woody biomass supply, such as Texas, where the 5% energy standard target would require a 5% supply contribution, and Florida a 3% contribution.

7. Under the proposed phased-in energy standards of the 2009 American Clean Energy Security Act and the 2009 American Clean Energy Leadership Act, it appears that the supply of woody biomass to meet the demand does not begin to compete with the traditional roundwood resource until 2017-20. At this time, the renewable electricity standard percentage allocation is between 9-17% depending on legislation. This does not include any adjustments downward for demand from either energy efficiency credits or alternative compliance payments.

Summary of Key Conclusions

1. Effective development and deployment of energy legislation should include woody biomass definitions that give consideration to how woody biomass is grown, procured, and harvested. Definition specifics may be best done in program development versus in the legislation itself.

2. Because of the disparity between where electricity demand is the greatest and woody biomass is relatively less available, a national RES should have compliance terms that are designed to take options for flexibility into account.

3. Under a scenario of increasing plant efficiency and utilization rates, a proposed RPS of 15-20% could feasibly be met with underutilized woody biomass until 2031, at which time it would then compete with the traditional roundwood resource.

4. In addition, new demand for woody biomass could improve market conditions so as to promote investment in reforestation and wood resource management, and improve the overall wood resource supply. However, the potential increase in future supplies due to increased planting, conversion of marginal lands to forested lands, etc., is not included in the study's projections.

5. Development of a stronger market for smaller diameter trees and brush intuitively should have a positive effect on ecosystem restoration through (1) fuel reduction in overstocked stands, (2) earlier thinnings to improve tree growth and stand vigor, and (3) invasive species removal. Even so, this appears to represent only 17% of the current available woody biomass supply and it is unclear at what cost this supply could be recovered.

6. Therefore, while it is unlikely woody biomass in the South could provide a maximum target of 20% without significant competition to existing timber markets in the short run, the phased-in approach to energy standard targets, along with the development of enhanced utilization and harvesting techniques and increased wood yields should allow for development of adequate resources for both bioenergy and traditional wood products.

Scope

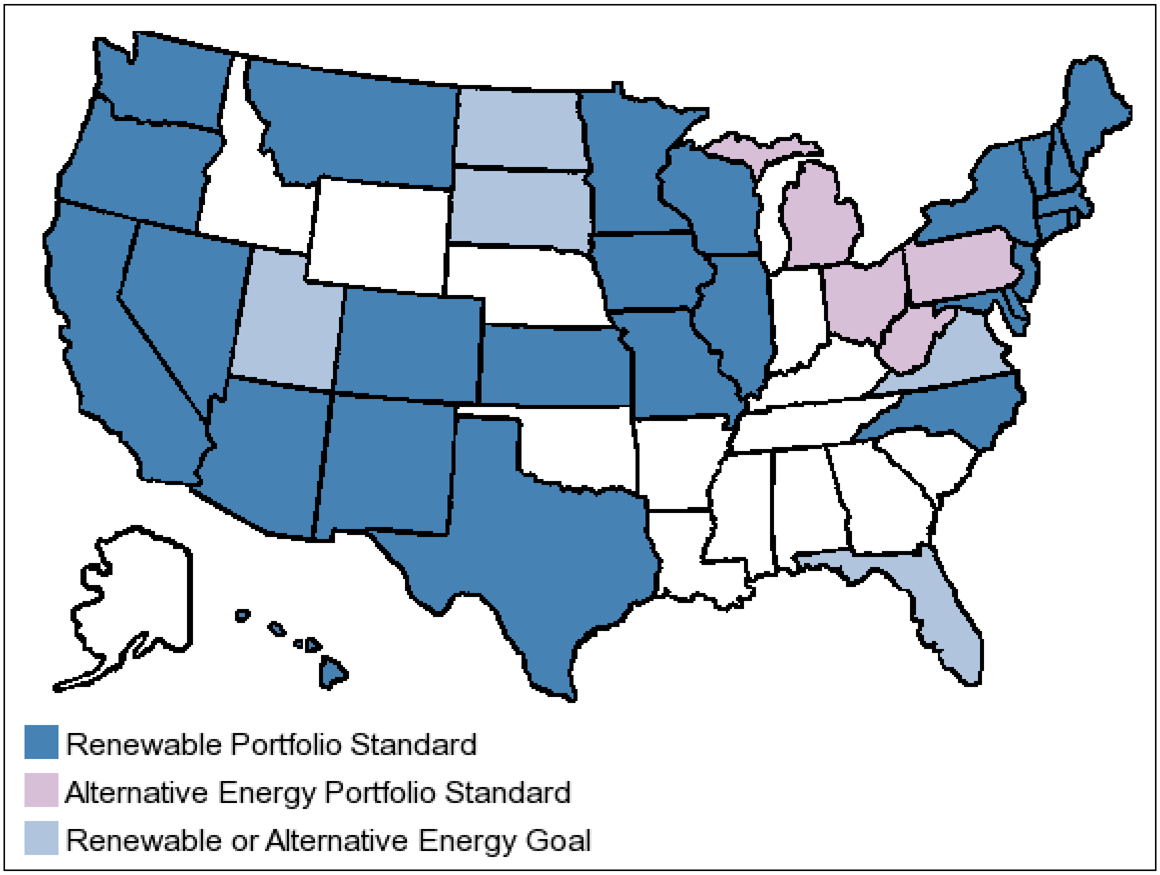
Woody Biomass Legislation and Definition

Biomass was first referenced by Congress in the Powerplant and Industrial Fuel Use Act of 1978 as a "type of alternate fuel." However, it was not defined until later in 1980 as part of the Energy Security Act as "any organic matter which is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants." (CRS Report R40529 Bracmort) Since then, the definition of biomass has expanded to include algae, construction debris, municipal solid waste, yard waste and food wastes. (Mintz 2010)

Recent interest in renewable energy as a means to gain energy independence, reduce rising energy costs and address climate change issues has resulted in several enacted and proposed pieces of legislation that feature biomass definitions, including most significantly the 2005 Energy Policy Act (EPAct), 2007 Energy Independence & Security Act (EISA), 2008 Farm Bill, 2007 Tax Code, 2009 American Clean Energy and Security Act (ACESA- Waxman-Markey) and the 2009 American Clean Energy Leadership Act (ACELA - Bingaman).

Two of these proposed pieces of legislation (ACESA and ACELA) include specifics related to energy standards for electricity commonly referred to as renewable portfolio standards (RPS) or renewable energy standards (RES). In addition to the federal RPS/RES being proposed in this legislation, 39 states and the District of Columbia have already enacted their own RPS/RES, mostly out of a desire "to spur economic development and create a reliable and diversified supply of electricity, as well as reduce greenhouse gas emissions and conventional pollutants." (Pew Center) However, it should be noted that only four states in the study area have done so: Texas, Florida, North Carolina and Virginia. (See Map 1) Because most of the legislation allows states to adopt their own standards, the debate on whether or not to implement a federal standard mainly involves the southeastern US.

Map 1 – States with Energy Standards



Source - Pew Center

Also included in the discussion of biomass definitions is legislation related to the federal requirement of the development and use of ethanol and other renewable, biomass-derived fuels between now and 2022. Commonly referred to as renewable fuel standard (RFS), these include the 2007 EISA and the 2008 Farm Bill.

Other legislation referencing biomass include the Biomass Crop Assistance Program of the 2008 Farm Bill and tax credits for producing fuel from non-conventional sources in the 2007 Tax Code. The current bill proposed by Lugar-Graham, Practical Energy and Climate Plan Acre (PECPA) includes a diversified energy standard (DES) which expands upon the RES/RPS/RFS concept so that it also includes technologies such as nuclear and coal generation with carbon capture and sequestration technology.

While the above represent some of the more significant references to biomass in energy legislation and policy, there are actually over "16 biomass definitions existing within recently enacted statutes, the Tax Code, and a Treasury Guidance" and "five additional definitions in pending energy bills." (Mintz 2010)

Primary to the woody biomass definitions is clarity as to what the definitions include, such as *nonmerchantable* materials, *i.e.*, logging residuals, understory shrubs, small trees, as well as what they do not include such as *merchantable* materials, *i.e.,* commercial first thinnings, late succession/old growth, etc. Also, central to the analysis of what the biomass definitions include, is how biomass is either grown or harvested, *i.e.,* as a designated energy crop, final harvest, partial thinning or sanitary cut. Additional designation is given in regard to the ownership of the land from which the biomass is harvested. Finally, there are parts of the various definitions and legislation implying that the "born on date" of the woody biomass resource will determine whether or not it is considered an "eligible" biomass feedstock.

Southern Timberland Resource

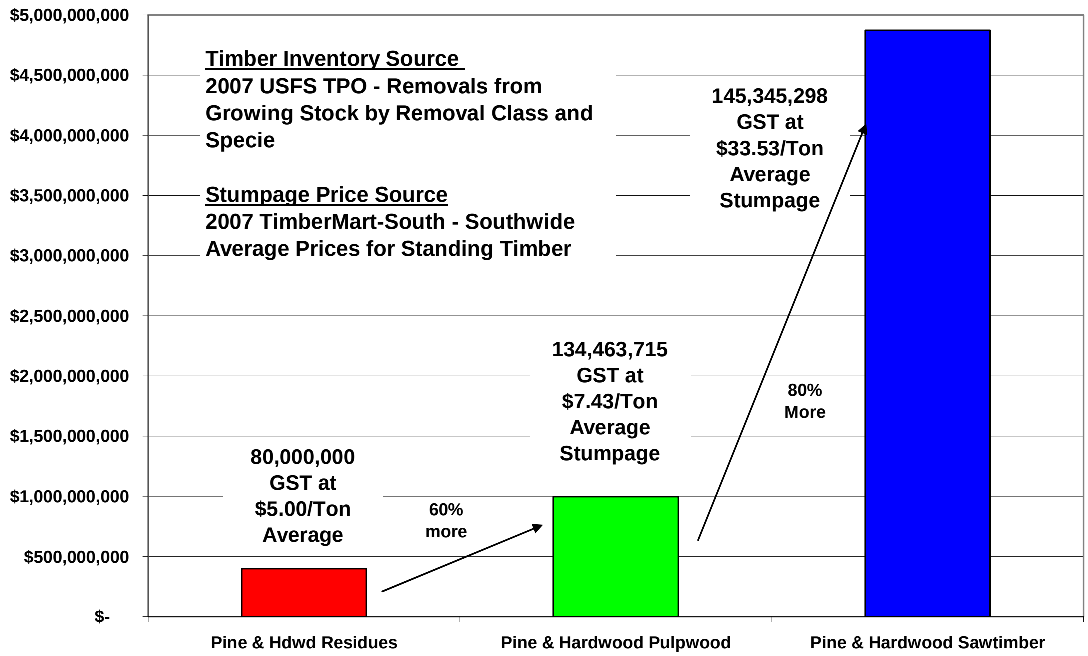
There are over 500 million acres of forested land in the lower 48 states, of which over 200 million acres are in the Southern region. The USDA Southern Research Station Forest Service Forest Inventory and Analysis group (FIA), who have been inventorying this resource since 1930, designate 13 states as the Southern region: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, the U.S. Virgin Islands and Virginia. All of these except Puerto Rico and the U.S. Virgin Islands are included in this study.

Certain characteristics of the South's forestland as compared to the rest of the United States are unique in relation to woody biomass supply and the proposed energy standards and biomass definitions. The South has the largest percentage of forestland in private ownership (88%) compared to the North (77%), Pacific Coast (42%) and the Rocky Mountain (27%). While most of the U.S. forestland is naturally regenerated (90%), the South has the largest percentage of softwood plantations (23%). Only 9% of the United States timber inventory is considered live cull trees, and the majority of the South species are hardwood. (Clutter 2010) Based on these characteristics, any biomass definition that restricts planted trees or hardwood species would seem to limit the available resource. Likewise, any definition or policy that relied on cull trees or softwood species could underutilize the resource.

Because so much of the forestland in the South is controlled by private ownership, it is important to understand how their behavior might influence availability of biomass in a market environment as well. Some of the highest growth rates are found on private timberland in the South, in large part due to the intensively managed pine plantations established by the private forestry products industry. This investment in intensive management has declined as much of the industrial landownership has been sold to private timberland investment companies. The potential to increase these annual growth rates also exists through current technological advances in forest management such as genetically improved species, fertilization, etc., but timberland owners must be convinced into investing in them through strong prices and steady market. According to a recent NAFO paper, "Forestland owners consistently make decisions with respect to long-term economics and, implied in the research, they feel neither compelled nor obligated to satisfy third-party target (*i.e.*, for energy production or to sell wood to new bioenergy plants) unless the economics make sense." (Mendell 2010)

Historically, timber markets have been driven by demand for solid wood products as well as pulp/paper products, which can follow very different business cycles. Depending on local market conditions, timber supply for solid wood products is worth 3-5 times as much as supply for pulp and paper products. For example, in 2007 the total tons of timber inventory removed for solid wood products and pulp/paper products was approximately 145 million and 134 million (TPO), respectively; however, using average stumpage prices for that same time period, the estimated value of those removals was $4.3 billion and $1.0 billion. In this same year, there were approximately 80 million GST of logging residues and other removals that could hypothetically represent a woody biomass supply. However, even at a very liberal estimated price of $5/GST, this theoretical biomass supply is only 40% of the value of the pulpwood market and 8% of the sawtimber market. (Figure 1)

Figure 1 Comparison of Potential Timber Market Values



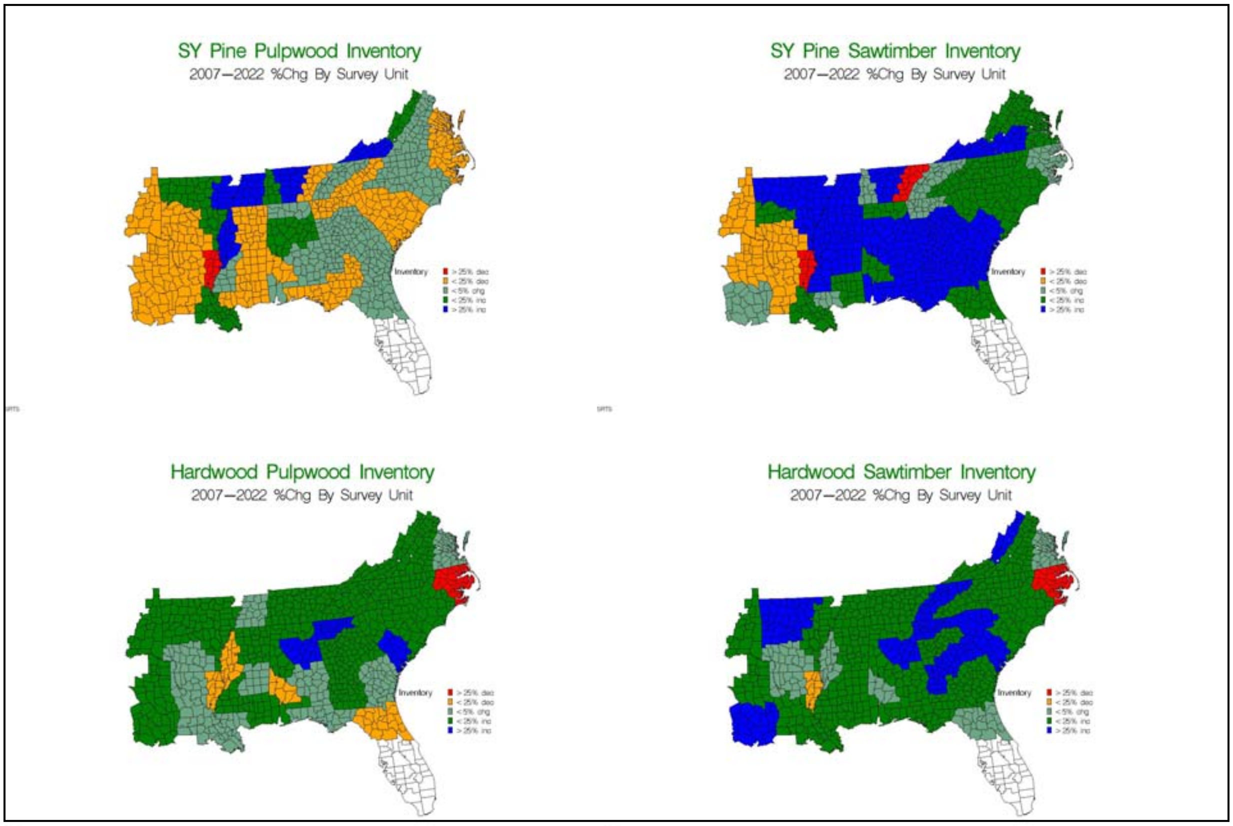
Based on this relationship between the primary timber markets, it is unlikely private landowners will shift their resource from sawtimber markets to biomass markets. On the other hand, it seems possible that demand for woody biomass might begin to compete for pulpwood markets because the margin between these prices is much smaller. (Figure 1) However, if markets become favorable enough, the opportunities and technologies available to increase growth rates might also mitigate any market share competition between biomass and pulpwood markets.

Timber Demand in the South

While demand for southern timber markets are some of the greatest in the world, harvest for all industrial roundwood products declined from 2005 to 2007 by 5.6% (TPO) Historical production in the South for pulpwood and sawtimber products peaked in 1999 and 2008, respectively. Real timber prices also declined during this time and research indicates that “returns to timberland owners are now substantially lower than they were in the 1990s”. (Wear 2007) During this same period, the southern timber inventory has been increasing. This reduction in demand in light of increasing supply would indicate a favorable market for additional timber consumption capacity.

The latest projections from the Southern Forest Resource Assessment Consortium (SOFAC) supports this overall increasing inventory trend with some notable exceptions in places like the Coastal Plains of Virginia and North Carolina, the entire state of South Carolina and parts of the West Gulf Region as seen below.

Figure 2 Southwide Regional Demand Runs SRTS Timber Supply Model (SOFAC/Abt 2010)



These exceptions are usually driven by local conditions such as urban growth, concentrated demand, etc. Because most wood consuming facilities procure their fiber resource in a 100-200 mile radius there is a limit to how much this local demand can be met with the excessive supply from other regions of the South. Also, because it takes 10-15 years for a timber to grow into merchantable volume, reforestation or management reactions by private landowners to supply this surplus local demand have a delayed effect on the actual available supply. Finally, because of large "sunk" costs associated with timber consumption facilities, entities are usually reluctant to "shut down" facilities and often operate at below cost for a certain period before they do so.

Timber Markets and Infrastructure in the South

Not only is adequate timber supply needed to meet local demand, but timber harvesting and transportation infrastructure must be available as well. Because of the high capital cost in timber harvesting, this sometimes can be an obstacle to entry in timber markets. However, as timber supply and demand market variables change in a location, “wood suppliers and loggers have adapted to new markets through improved forest management, increment growth of logging operations and utilization of previously underutilized raw materials” (Clutter 2010) but it takes time.

Likewise, any examination of potential biomass supply, under different definitions of woody biomass, must take into consideration not only the current supply/demand on the timber resource, but also the local aspects of how timber is harvested and delivered in the South. Most private landowners manage their timberland so that it is capable of producing multiple products at various time intervals. For example, in natural stands, they might remove a certain number of trees at different intervals in the natural life of the stand. In each harvest operation, the trees removed could be of size and quality for either pulpwood or sawtimber products. Conversely in planted stands, a landowner might remove only smaller, pulpwood size trees so as to improve the overall condition of the stand for producing larger sawtimber quality trees later on. Each landowner is also restricted by the productivity potential of their land, be it inherent or enhanced.

Depending on the location market, as well as the size and price for sawtimber and pulpwood products, the management decisions of the landowner will vary. For example, in predominately pulpwood markets, a landowner might manage under shorter rotations so to continuously produce pulpwood trees. In a sawtimber market, they might extend rotations to match the local demands. In many cases, there are adequate markets for both pulpwood and sawtimber markets such that a landowner will manage for the multiple products, attempting to time harvests for peak market demands and prices. Figure 3 illustrates how trees can be removed and others left in a partial thinning, as well as the variety of sizes that are included in one harvest operation.

In addition to deciding when and how to cut a stand, decisions are made on how to “merchandize” individual trees in the harvest operation because trees themselves have different components. For example, the middle section of the tree (bole) might go to a local sawmill for lumber while the tops and branches may go to a local pulpmill. Some of the smallest trees may be chipped up on the site and transported as chips to a local fuel or pulpwood mill. (Figure 4)

Finally, because the biomass definitions seem to imply the need for chain of custody verification, understanding how woody biomass transactions might occur is of interest. As mentioned above, the majority of timberland is owned by private landowners; however, there is an extensive network of timber dealers or managers who purchase and resell timber to end users either on behalf of the interest of the landowner or as independent brokers.

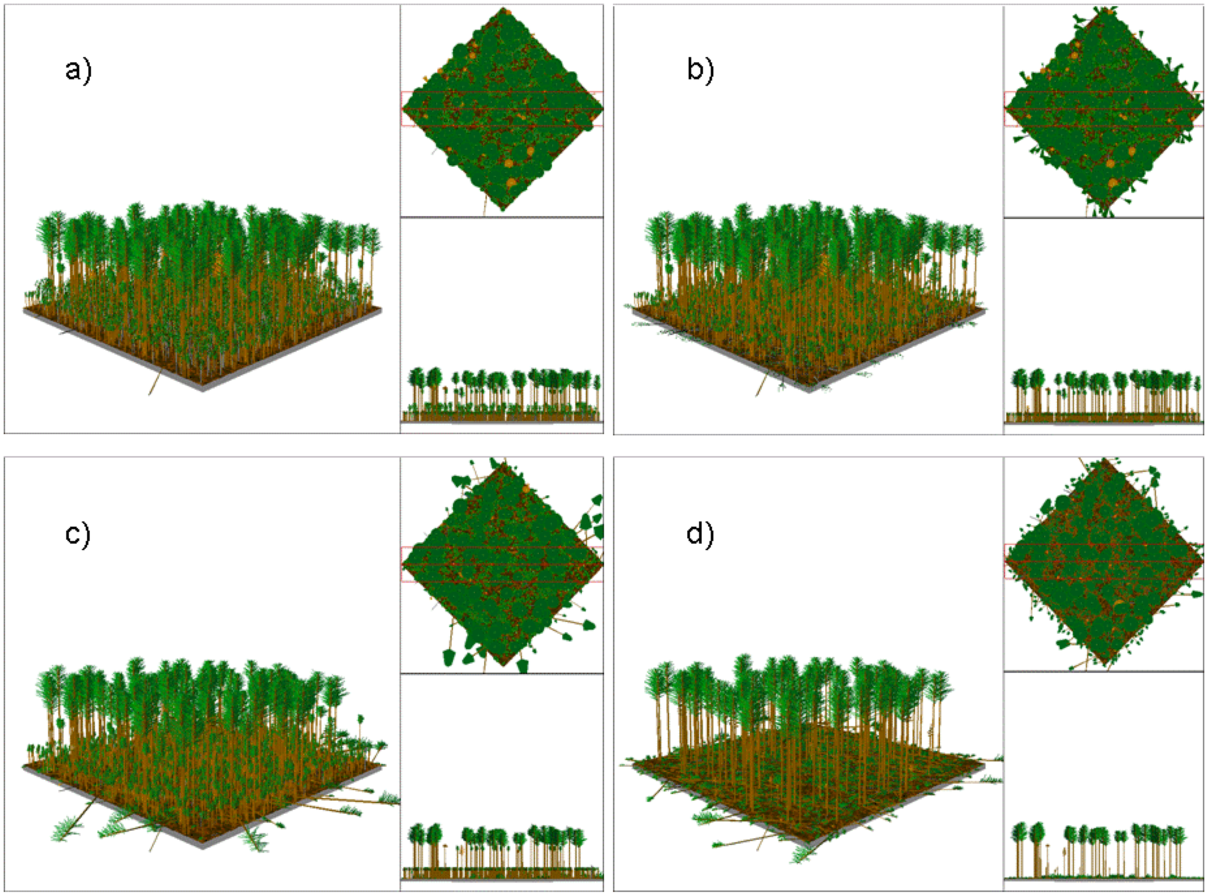


Figure 3 Visual display of thinning prescription on a sample pine plantation stand (Source - Texas Forest Service – Burl, et al.)

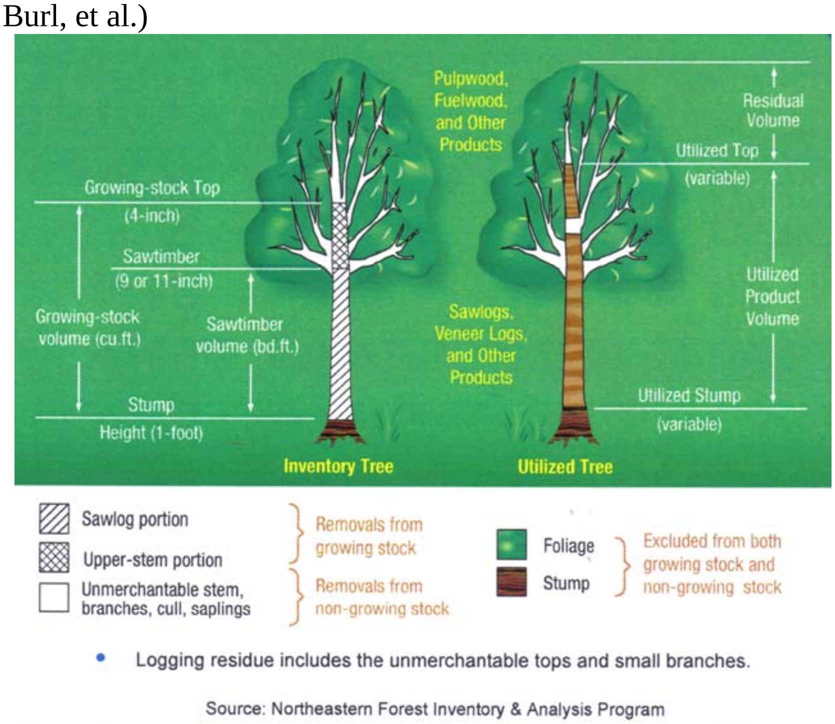


Figure 4 Comparison of how a tree is inventoried vs. utilized – (Source – Billion Tons Study)

Energy Demand and Electricity Production in the South

In 2008, *energy consumption* in the South was divided between industrial 38%, transportation 27%, residential 19% and commercial 16%. The primary fuel sources for *electricity generation* in the South were coal (41%), natural gas (28%) and nuclear (20%). Renewables only comprised 4.56% with woody and wood derived fuels being only 27% of those renewables, or 1% of all fuels. (EIA) The greatest use of this biomass fuel has been by the forest products industry itself, which consumes about 85% of all wood and wood waste used for energy and is the second-largest consumer of electricity in the industrial sector. (DOE EIA)

Electricity power generation in the South increased annually by 3% from 1990 to 1999, but only 1% from 2000-2008. Because population and GDP growth have the greatest influence on electricity demand, and with shifting population to the South and warmer climates, there might logically be expected increase in demand instead of decrease in the last decade. However, energy efficiency gains through energy management practices, advanced technologies and efficient process designs, as well as slow growth in industrial production, have been credited with the offset of this demand. (DOE EIA) The continued development of these energy efficiency systems and energy conservation incentives should therefore have significant effect on the amount of electricity needed in the future.

Most biomass fueled electricity involves direct fire or co-fire generation, and operate only at 50% efficiency, while there are other available technologies and systems such as combined heat and power (CHP) that approach 90% efficiency. Both the ACES and ACELA have provisions for allowing energy efficiency to be used as a percentage of the energy target in their RES which should encourage the use of such systems and influence the total demand for biomass in the future. These include the use of energy efficiency as a certain percentage of its RES requirements as well as the use of an alternative compliance payment mechanism that allows a utility to make a payment if the marginal cost of using renewable power falls within certain parameters.

Modeling Future Timber Supply and Demand

The U.S. Forest Service has been analyzing future timber supply and demand since 1958, and in 1974, with the passage of the Renewable Resource Planning Act (RPA), started developing projections using various econometric models and FIA data. From these efforts, the Subregional Timber Supply (SRTS) model was developed in 1994 to disaggregate the demand and supply to the South. This econometric model has since been used extensively to project timber supply for USFS projects, as well as individual studies for policy issues such as chipmill influences on regional supply. Currently in its second generation, the SRTS model now allows analysis of user-defined multi-product demand scenarios, improved regional analysis of inventory and growth assumptions and projections of logging residuals. The SRTS model uses the most current FIA inventory data as the base inventory and then models annual supply as a function of stumpage price and inventory, while simultaneously determining through the market equilibrium calculations the annual demand or harvest. It uses price elasticity functions, empirical growth data from FIA and land use change assumptions. Outputs from the model include harvest, inventory and growth volumes by product, subregion and owner as well as age class and tree size. The logging residuals include projections from growing stock and non-growing stock inventory. A detailed description of the SRTS model can be found in Abt et al., 2009 and Prestemon and Abt, 2002.

Methods, Data Sources and Findings

Identification of Biomass Definitions

Our review of the biomass definitions in enacted and proposed legislation identified sixteen unique definitions of woody biomass in enacted and six in proposed. Most of these definitions are vague and typically varied by the type of forestry products that could be used and the lands available for removal. For example, the EISA bill includes a condition of "not forests or forestlands that are ecological communities with a global or State ranking" while the Farm Bill does not include such a condition in its very detailed and precise definition of biomass. Likewise, the Farm Bill and ACESA allow biomass removal from federal lands while the EISA prohibits it, and other legislation fails to specifically address it altogether. Therefore, public lands is not considered as available supply in this study. Currently, these lands represent very little of the timber removals in the South and the SRTS supply model does not have a mechanism to address them as well.

Use of global ranking definitions in the U.S. National Vegetation Classification (USNVC) system was investigated as a technique for establishing how much woody biomass might be affected by a restriction on ecological communities. These rankings are based on specie associations and alliances. However, because of limits in the data available to measure biomass resource, the application of these rankings is not straightforward enough. Another tool investigated is the national and state lists of rare and endangered species occurrences maintained by the U.S. Fish & Wildlife Service and individual state Natural Heritage programs. Variability of how this data is collected among states, and the fact that it only includes areas of known significant ecological communities, prohibits its use as well. Likewise, the Gap Analysis Program, a multi-agency program being developed to use species alliances and endangered listings as the standard for state vegetation cover maps, is not complete enough to be used as well. Because none of these data sources are sufficient, the biomass supply is restricted to stands less than 80 years old as a way to mimic a constraint due to ecologically sensitive lands. This only represents 7% of the available supply for the South, however.

The analysis of the biomass definitions is then narrowed to focus on those that specifically address woody biomass. Consideration is given to whether or not the definition could be estimated or modeled for assessing implications for supply and if data was available. Initially, the various aspects of the definitions are assigned to unique pieces of legislation (Appendix A - Biomass Definition Legislation Matrix) and then they are assigned to a scenario spectrum of permissive to restrictive. (Appendix B – Biomass Definition Spectrum). Eventually, both the legislative definitions and the data parameters of the inventory data, help create biomass supply buckets that are grouped together in various combinations to present different proposed definitions. The buckets primarily represent designations between the types of tree and their various components as well as the type or condition of stand from which it is removed.

Table 1 - Biomass Supply Buckets

<u>Tree Component Grouping</u>

1. **Plant Residues** - Wood Waste Material Generated at Primary Manufacturing Plants
2. **Slash & Brush -** Underutilized and Non-Commercial species
3. **Logging Residue** - Tops, Branches and Unused bole of merchantable trees
4. **Pulpwood Tree Volume –** The portion of live trees 5.0 inches DBH and above not allocated to saw-log section of the tree
5. **Small Sawtimber Tree Volume –** The saw-log section of live trees 10-12 DBH only
6. **Salvage from Fire, Insect & Disease** - All tree volume associated with damaged stands
7. **Older Age Stands –** All tree volume in stands 80 years and older

<u>Stand Type or Condition Grouping</u>

1. **Planted –** All stands having planted origin
2. **Natural –** All stands not having planted origin
3. **Pre-Merchantable** – Stands 0-10 Years
4. **Merchantable** – Stands >10 Years

Measuring Woody Biomass in the Forest Resource

Information is collected by FIA through an annual survey of permanent forest plots to monitor and assess the quantity and quality of the Southern forestland. Data collected include tree sizes, species, age, growth, forest type, location, ownership, removals, etc. We use this data to provide various estimates of volume by growing stock and non-growing stock. Traditionally, these estimates have been used to estimate commercial volumes such as board feet, cubic feet or green short tons. Recently, biomass volume equations have been revised and used by FIA to provide dry weight of individual tree components (stemwood, top, branches, bark, stump and coarse roots) before estimating the total biomass of the tree. The approach, called the component ratio method (CRM), also utilizes a compiled set of specie and bark specific gravities to adjust green weight volumes. For smaller trees (saplings and woodland species), only a total biomass value representing wood and bark from ground to tip excluding foliage is available.(See Appendix C – Biomass Estimation in FIADB)

In the study, a database (Biomass Database) is created from FIA plot level data for various FIA data parameters. It provides acres by stocking levels, site class, management type, damaged class and age class. It also provides dry tons by stocking levels, site class, management type, damage class, age classes as well as tree class and diameter class. Using the database, we estimate biomass for the supply buckets by calculating volume and dry tons for the various tree components using the following criteria.

- <u>**Mervolsum**</u>-sum of net merchantable volume in cubic feet (1 foot stump to 4 inch top bole diameter). This is the traditional FIA volume variable.
- <u>**Sawcfsum**</u>-sum of net volume of saw-log section in cubic feet. This is a subset of Mervolsum. Only populated for growing stock trees of sawtimber size.

- **Bolewtsum**-sum of dry weight of the merchantable bole in tons.
- **Sawwtsum-**sum of dry weight of the saw-log section in tons.
- **Upstemwtsum**-sum of dry weight (tons) in the upper stem (saw-log top to 4.0 inch bole diameter) of sawtimber trees.
- **Stumpwtsum**-sum of dry weight (tons) in the stump (ground level to 1.0 foot above ground) of trees 5.0 inches d.b.h. and larger.
- **Topwtsum**--sum of dry weight (tons) in the top of trees 5.0 inches d.b.h. and larger. Includes bole from 4.0 inch top diameter to tip and all branches. Does not include foliage.
- **Sapwtsum**--sum of dry weight (tons) of trees 1.0-4.9 inches d.b.h.

The database allows for query by either state or FIA unit and also includes acres by FIA agricultural class. A complete data listing of the Biomass Database is in Appendix D.

As shown in Figure 5, over 45% of potential woody biomass feedstocks are in underutilized product types, *i.e.*, damage, logging residuals. Figure 6 demonstrates how that supply is reduced if it is restricted by planted or natural stand type or merchantable or premerchantable trees. A complete summary of the biomass supply buckets by state is in Appendix E.

Figure 5 - Current Woody Biomass by Supply Buckets - Total South

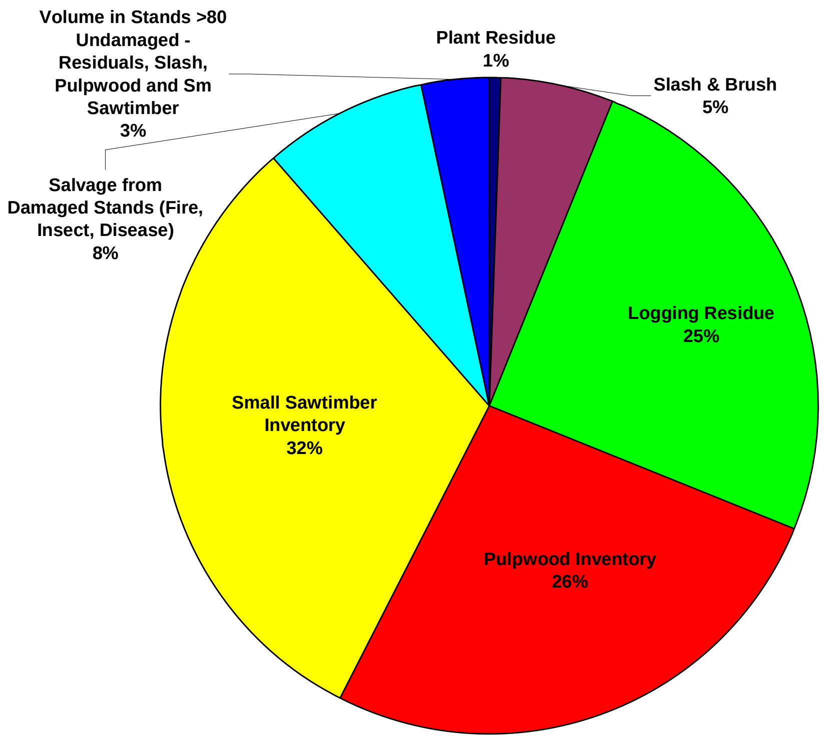
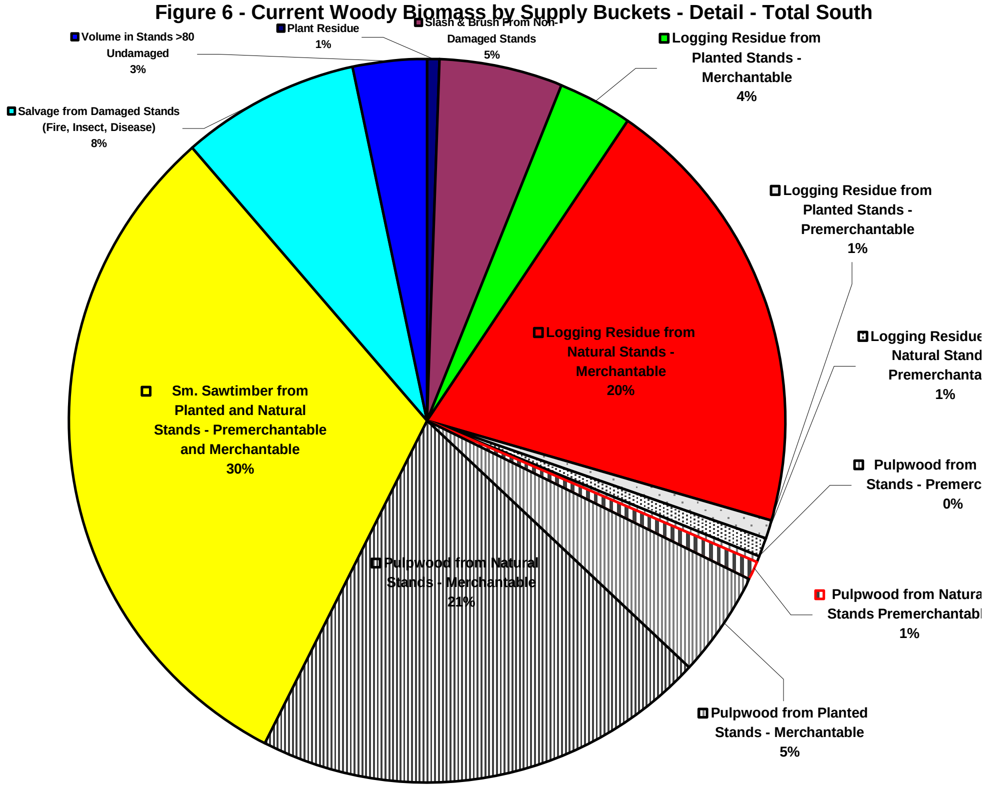


Figure 6 - Current Woody Biomass by Supply Buckets - Detail - Total South



Calculation of Electricity Demand for Woody Biomass in the South

The 2008 annual electricity generation by state by megawatt hours is used to calculate initial baseline demand estimates. (DOE EIA 2010) Excluded from this demand is hydroelectric power generated in each state. We use the average annual electricity generation rate change from 2000-2008 for each state, along with their baseline demand, to calculate annual future demand. In some states, like Tennessee and Virginia, this is actually 0 or -1% growth rate in electricity. The average growth rate is 1.5% for the study area.

We also use two energy target scenarios to mimic legislation definition options (ACESA and ACELA) and calculate the "renewable" energy requirement of each from these baseline demands. Netted from these percentages is the current percentage already supplied by other renewable feedstocks such as solar, wind, etc. No attempt is made to project increases in these other renewable feedstocks as a component of future renewable energy requirements.

Because, the energy standards have graduated percentages for annual time periods, there is a stair step increase in annual electricity demand. This stair step demand is also influenced by the different electricity growth rates in each state. Also, some states, such as Texas, Oklahoma and Louisiana, are already meeting the initial energy standards requirement with current renewable fuel sources. Their biomass demand estimate is delayed a few years after the initial period until electricity demand gets great enough to need additional renewable energy or the percentage requirement increases.

Table 2 – Energy Standard Scenarios Modeled in Study

ACESA		**ACELA**	
Target	Time Period	Target	Time Period
6%	2012-2013	3%	2011-2013
10%	2014-2015	6%	2014-2016
13%	2016-2017	9%	2017-2018
17%	2018-2019	12%	2019-2020
20%	2020-2039	15%	2021-2039

We use two energy *efficiency* scenarios to calculate the dry tons of woody biomass needed for each of the energy *standard* scenarios. Included in these scenarios are two different conversions of BTU/LB because while the biomass equations provide dry tons, it is unclear as to what moisture content that represents. Scenario A assumes 26.25% energy efficiency and 6,400 BTU/LB, air dry, 20% moisture. (Source – US National Institute of Standards and Technology –NIST) This scenario represents a more conservative estimate as it includes current technology and lower heating values (LHV) of wood. Because of the variability in density and moisture among different tree species, there is a range of values for the actual heating value of wood. Scenario B assumes 40% energy efficiency and higher heating value (HHV) or 8,600 BTU/LB, bone dry, no moisture. (NIST) This scenario represents gains in technology efficiencies.

Calculating Wood Utilization and Availability

Harvest yields of woody biomass vary among by tract size, stocking levels, removal volumes and tree species. As markets have increased for woody biomass, advances in harvesting techniques have increased these yields. The Biomass Database derived from the FIA plot data provides data parameters useful for modeling these variable yields. For this study, we use two wood utilization scenarios (Base and High) to represent current utilization and potential increase for each of the biomass supply buckets. (See Table 3) Included in each of these yields are assumptions of availability in regard to other existing markets. For example, for the pulpwood biomass supply bucket only 25% is assumed to be available due to already existing traditional pulpwood markets.

As is shown in Figure 7, the total biomass resource is reduced to only 27% available after applying the base utilization/availability rates. In Figure 8, this available biomass supply by each state is compared to its annual energy demand for various percentages. For some states there appears to be a positive relationship of biomass supply to demand (ex., AR, MS) and in others there is a negative relationship, (ex., FL, TX).

Table 3 –Utilization/Availability Rates Scenarios

	Scenario A - Base		**Scenario B – High**	
Supply Bucket	**Utilization**	**Annual Increase**	**Utilization**	**Annual Increase**
Res_Plt_Mer	60%	1.9%	70%	2.5%
Res_Nat_Mer	50%	1.9%	60%	2.5%
Res_Plt_PM	60%	1.9%	70%	2.5%
Res_Nat_PM	50%	1.9%	60%	2.5%
Pulp_Plt_PM	75%	0.0%	80%	1.9%
Pulp_Nat_PM	75%	0.0%	80%	1.9%
Pulp_Plt_Mer	25%	2.5%	25%	2.0%
Pulp_Nat_Mer	25%	2.5%	25%	5.0%
Sm_Saw_All	10%	1.0%	10%	2.5%
Older Age	0%	0.0%	0%	0.0%
Damaged Stands	0%	0.0%	0%	0.0%

Definition

Res=Logging Residues

Plt=Planted Stands

Nat=Natural Stands

Mer=Merchantable Stands >10 years

PM=PreMerchantable Stands <10 years

Pulp=Pulpwood

Sm_Saw=Small Sawtimber 10-12 DBH

Figure 7 - Current Woody Biomass By Supply Buckets AND Availability - Total South

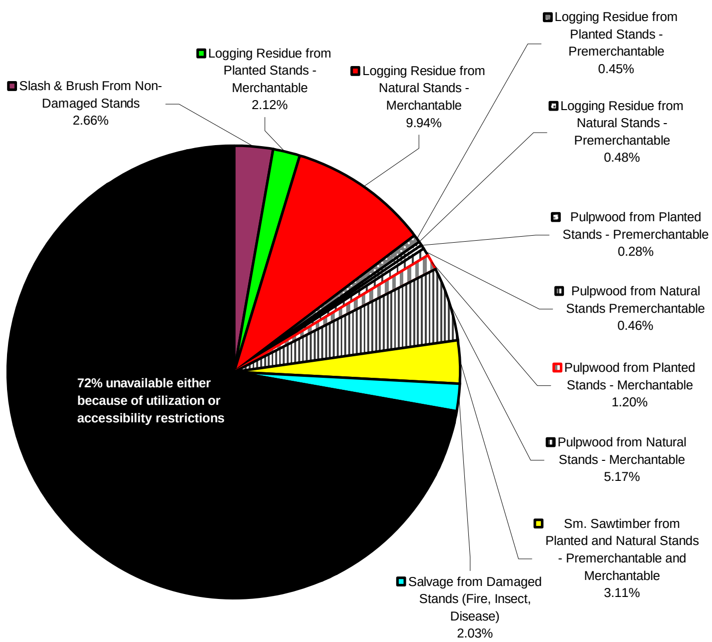
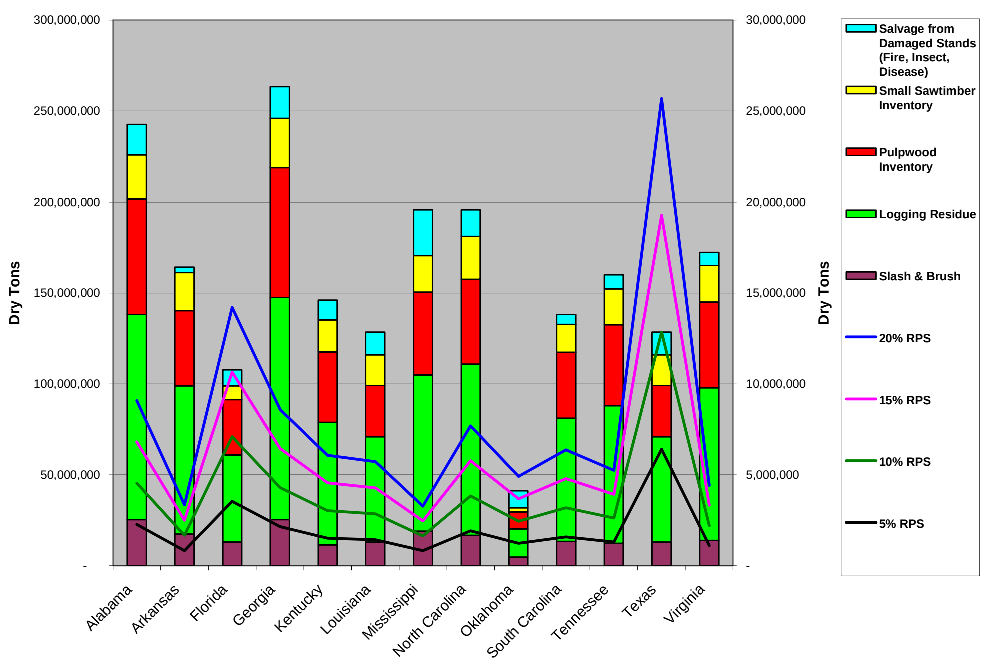


Figure 8 - Comparison of Total Woody Biomass Supply AVAILABLE and 2010 Estimated Annual Electricity Production Levels by States in Study Area



Modeling Timber Supply and Demand

To estimate the future biomass supply buckets, we use a base demand SRTS run for the entire study area to represent the current demand of the existing wood consuming industries. However, because of the periodic nature of the underlying FIA data, both the inventory and empirical growth/removal data are actually dated. Instead of reflecting inventory and growth/removals for 2008 (the last periodic inventory date), the weighted average inventory age for the study area is really 2005 and the mean growth/removal year is 2002. (Sheffield) While the SRTS model allows for adjustments to the empirical growth/removal ratios, we did not adjust for any discrepancy of these starting points in this study. As pulpwood production has been declining since 1999 and sawtimber production increasing until 2008, the 2002 growth/removal ratios perhaps represent the average of these periods. Also, because of observed decline in intensive forest management in recent years, the growth rates are thought to be adequate for future yields of recently established plantations. Additional refinements of the study, however, might consider adjustments of these growth/removal estimates to reflect potential increases from intensive forest management practices and more current removal rates.

Using SRTS output files we derive woody biomass estimates for the supply buckets outlined in Table 1 and Table 3 using the following methods.

For the Slash/Brush and Logging Residue supply buckets we use the logging residuals calculated in the SRTS model. It applies FIA TPO logging residual factors by species and residual size class to growing stock removals, and provides estimates not only for residuals from growing stock inventory but also from non-growing stock. The growing stock would represent the Logging Residue supply bucket derived from the Biomass Database while the non-growing stock would represent the Slash/Brush supply bucket. These factors are based on state-level field studies of typical logging jobs and vary by state. (Appendix G) They are influenced by both the available supply, *i.e.*, tops, limbs, understory, as well as the recovery rates for each specie. The southwide average for pine residuals is 8% growing stock and 16% non-growing stock. For hardwood it is greater, 16% from growing stock and 27% from non-growing stock inventory. We use the proportion of SRTS removals by management type and age class to allocate the residuals by planted and natural, as well as premerchantable harvest and merchantable harvest. We assume that 100% of these annual residuals are available for biomass supply.

For the premerchantable pulpwood harvest volumes, we apply the same harvest rate of the 16-20 age class by stand type and diameter class to the growing stock inventory below age 15. We assume this growing stock removal would qualify for a precommercial or biomass harvest operation.

We use the SRTS removals by d.b.h. and age class to estimate the percentage of the annual removals that would qualify for the pulpwood and small sawtimber merchantable supply buckets.

Because SRTS does not include a mechanism to quantify damage stands nor does it include projections of plant residuals, we assume zero availability for these buckets.

When we compare the relationship of the supply buckets derived from the SRTS model outputs to the FIA Biomass Database (Table 4), we observe overall similar trends in that most of the residuals are in the natural stand types and very little inventory is available in the premerchantable supply buckets. However, the SRTS model only projects about a third of the inventory in pulpwood natural supply bucket compared to the Biomass Database and about 20% more in the small sawtimber supply bucket. This could be both from the influence of harvest patterns as well as difference in product specification differences. When supply is restricted for utilization and availability, residues make up almost half of the available supply; both estimates and merchantable pulpwood and sawtimber supply are reduced significantly.

Table 4 - Comparison of Supply Bucket Estimates

	Scenario A - Base		**Scenario B - High**	
Supply Bucket	**Utilization**	**Annual Increase**	**Utilization**	**Annual Increase**
Res_Plt_Mer	60%	1.9%	70%	2.5%
Res_Nat_Mer	50%	1.9%	60%	2.5%
Res_Plt_PM	60%	1.9%	70%	2.5%
Res_Nat_PM	50%	1.9%	60%	2.5%
Pulp_Plt_PM	75%	0.0%	80%	1.9%
Pulp_Nat_PM	75%	0.0%	80%	1.9%
Pulp_Plt_Mer	25%	2.5%	25%	2.0%
Pulp_Nat_Mer	25%	2.5%	25%	5.0%
Sm_Saw_All	10%	1.0%	10%	2.5%
Older Age	0%	0.0%	0%	0.0%
Damaged Stands	0%	0.0%	0%	0.0%

Definition

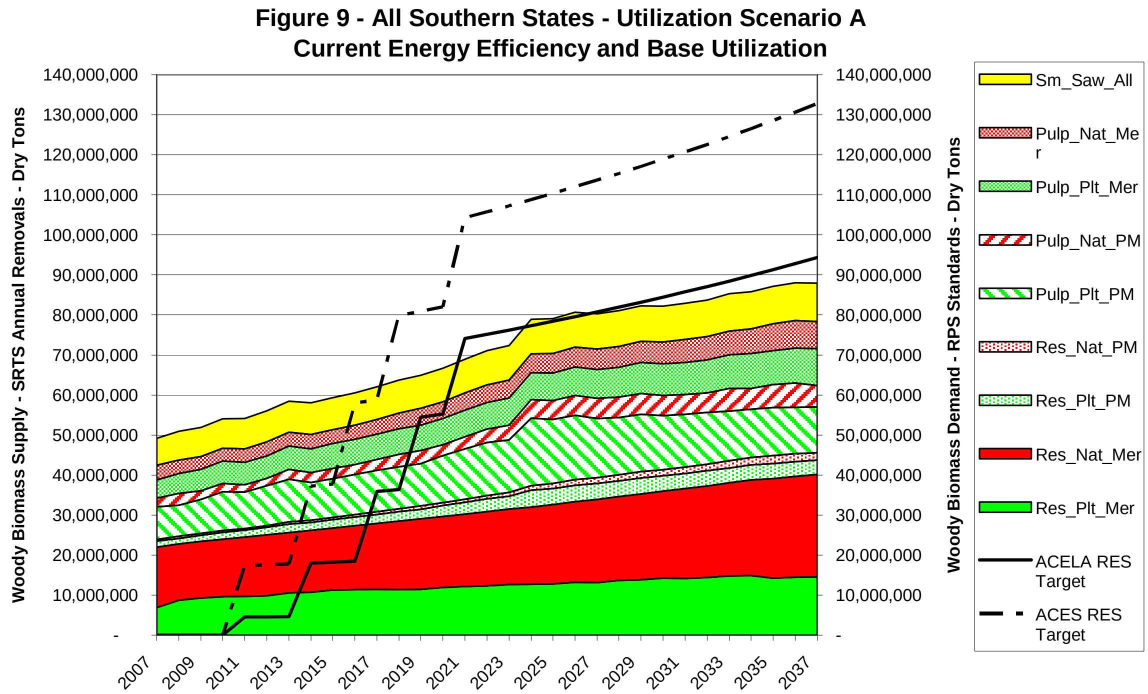
Res=Logging Residues
Plt=Planted Stands
Nat=Natural Stands
Mer=Merchantable Stands >10 years
PM=PreMerchantable Stands <10 years
Pulp=Pulpwood
Sm_Saw=Small Sawtimber 10-12 DBH

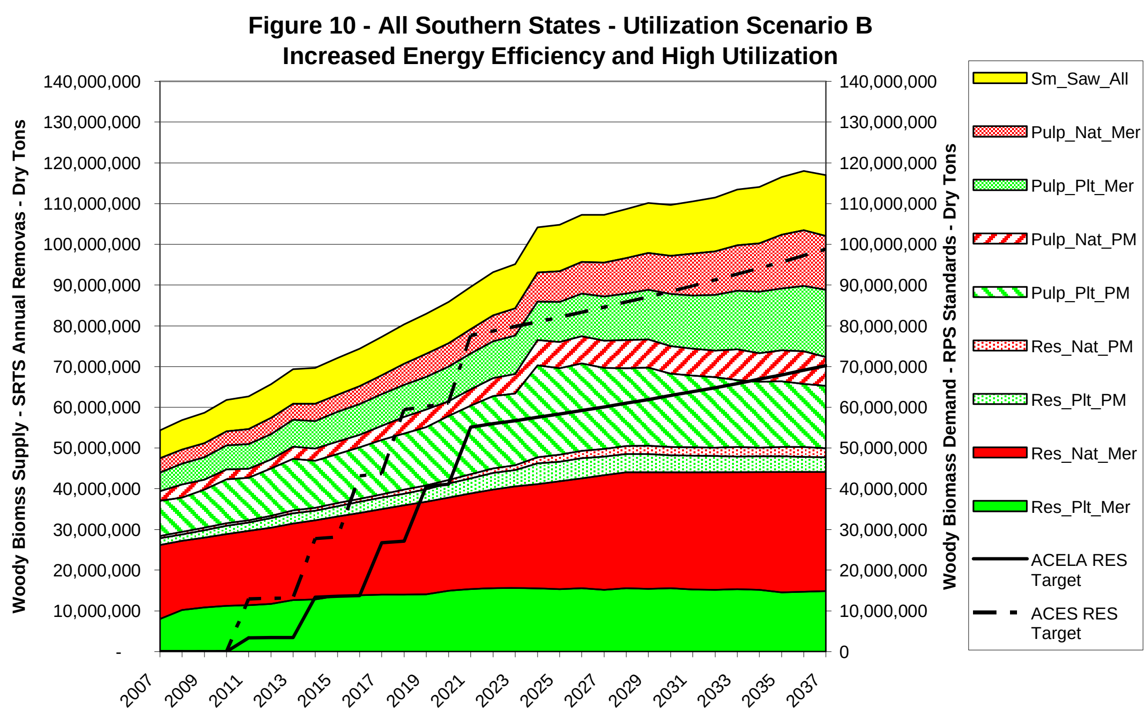
SRTS annual removals for the base year of the projections, in dry tons, is 162,045,275 dry tons. The estimate biomass supply bucket for pulpwood and small sawtimber from merchantable stands is 27,104,792 dry tons. This indicates that a potential biomass market would have to compete for 18% of the traditional roundwood market.

Figures 9 and 10 compare the projected SRTS biomass annual removals to the two energy efficiency and wood utilizations scenarios for the entire study area. Based on this comparison, it appears that demand for woody biomass for either of the energy standard scenarios would not compete with the traditional roundwood markets represented by the Pulp_Nat_Mer and Pulp _Plt_Mer layers until 2017-2020 under current energy efficiency and base utilization, Scenario A. With increased energy efficiency and high utilization, Scenario B, this is extended until 2020 for the ACESA energy standard. For the ACELA standard, the biomass requirements appear to be met throughout the projection by residuals and premerchantable pulpwood. Appendix H contains a similar comparison for each state.

As was observed in the comparison of the Biomass Database current supply estimates, there are some states where demand is adequately met with the projected available biomass supply. In others this is not the case. For example, Alabama, Arkansas, Louisiana, Mississippi, North Carolina and Virginia, all follow a similar trend as the Southern States except in some states, under Utilization Scenario B, both energy standards are meet with non-traditional wood products, ie residuals and premerchantable pulpwood. However, some states such as Florida and Texas, the demand for woody biomass can not be meet under either scenario or energy standard, because of large demand for energy relative to the timberland resource in the state. Likewise, states with similar limited timber resources but less demand, Kentucky, Tennessee and Oklahoma, could also not meet the energy standards under either scenario. Finally, two states, Georgia and South Carolina, appear able to meet the energy standards with the residuals and premerchantable pulpwood exclusively under either energy efficiency scenario. Also it should be noted that eliminating biomass from natural stands would adversely affected all states except Alabama, Georgia, Florida or Texas, who either have large inventories of planted pine stands or very little natural timber stands relative to planted.

Comparison of Future Biomass Supply to Demand





Conclusions and Recommendations

Because of numerous and contradictory definitions in current and proposed energy legislation, effective development and deployment of energy legislation needs to include both more definitive and descriptive definitions that are consistent with how woody biomass is grown, measured and procured. The above biomass supply/demand estimates are based on component supply buckets and tree/stand data, making adjustments possible as inclusions or exclusions are made to the legislative definition of woody biomass.

The utilization and availability of woody biomass from the Southern timber resource will also continue to be adjusted through advances in harvesting technology and forest management practices. By developing an estimation process and Woody Biomass Database that utilizes FIA plot inventory data and underlying assumptions on utilization and availability, the potential supply can be adjusted and updated as new inventory data and assumptions become available.

Demand for woody biomass to meet renewable energy standards will be influenced by availability of other alternative fuels, advancement of energy efficiency technologies and land use changes. The two energy demand scenarios used in this analysis do not take into consideration all these factors and use general assumptions in regard to wood to energy conversion and utilization rates. Additional analysis of the demand assumptions and calculations might yield varying results and could be considered in future analysis.

Also, while the above analysis estimates available woody biomass by supply buckets and contrasts these to traditional forest product demand, it should be noted that no consideration was made for market share in regard to cost. Additional analysis is needed to determine at what cost this supply becomes unavailable as well as the price differential between woody biomass and traditional wood products. These, also, will influence assumptions of future supply.

Finally, by using the same underlying data, estimation process and utilization assumptions, comparison between states or regions becomes more transparent. However, variability among regions in regard to these assumptions is possible and further refinement of the analysis to include these is possible. Also, spatial representation of the supply and demand, *i.e.*, maps, procurement zone analysis, plant locations, etc., would aid in the analysis of sustainability and regional variation and should be considered is a possible extension of this study.

Appendix

Appendix A - Biomass Legislation Definition Matrix

Major Legislation																	
Source	Energy Policy Act - EPAct						Energy Indep. & Secruity Act - EISA			Tax Code				Farm Bill	ACESA - Waxman		ACELA - Bingman
Year	2005						2007			2007				2008	2009		2009
Reference	Title II Sec 203(b)(I)	Title II Sec. 206 (a)(6)(B)	Title II Sec 210(a)(I)	Title IX Sec 932(a)(I)	Title XIII Sec 1307, Sec. 48B(c)(4)	Title XV Sec. 1512(r)(4)(B)	Title II Sec 201(I)(I)	Title XII Sec 1201	Tiltle XII Sec 1203(e)(z)(4)(A)	Title 26 Sec. 45(c)(2)	Title 26 Sec. 45(c)(3)	Title 26 Sec. 45k(c)(3)	Title 26 Sec. 48b(c)(4)	Title IX Sec 9001	2454 House Introduced	2454 House Passed	1462 Senate Introduced
Purpose / Biomass Sources That Can be Modeled	Fed. Gov. Purchase Requirement for Renewable Energy	Renewable Energy Security Provision	Grants fo Improve Commercial Value of Forest Biomass for Electric Enegry, Useful Heat, Transportation Fuels and Other Commercial Purposes	Bioenergy Program	Credit for Investment in Clean Coal Facilities	Conversion Assistance for Cellulosic Biomass, Waste-Derived Ethanol, Approved Renewable Fuels Grants Program	Renewable Fuel Standard	Express Loans for Renewable Energy and Energy Efficiency	Small Business Energy Efficiency Program	Electricity Produced from Certain Renewable Resources - Closed Loop	Electricity Produced from Certain Renewable Resources - Open Loop	Tax Credit for Producing Fuel from a Nonconventional Source	Qualifying Gasification Project Credit	Biorefiniery Assistance, Repowering Assistance, Biomass Res & Dev Initiative, BCAP, Forest Biomass for Energy, Community Wood Energy Program		20% by 2020, 2.5% productivity inc, cap & trade for GHG	Requires utilities to obtain increasing % of electricity from renewable energy, 3% 2011-2013, 6% 2014-2016, 9% 2017-2018, 12% 2019-2020, 15% 2021-2039
Logging Residue	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Thinnings, Slash, Brush							yes					yes		yes			
Salvage Timber												yes		yes			
Hazard Reduction							yes					yes		yes			
ROW Clearing												yes		yes			
Late Succession/Old Growth							no					yes		yes			
Critically Imperiled							no					yes		yes			
"Designated" Tree Energy Crops Old								yes	yes	yes	no	yes	no	yes			
"Designated" Tree Energy Crops New								yes	yes	yes	no	yes	no	yes			
"Actively" Managed Plantations Old							yes			no	yes	yes		yes			
"Actively" Managed Plantations New							yes			no	yes	yes		yes			
Naturally Regenerated wood							?			no	yes	yes		yes			

Appendix A - Biomass Legislation Definition Matrix - Continued

Minor Legislation

Source	American Power Act - Kerry-Lieberman	Clean Air Act Amendment			American Conservation & Clean Energy Independence Act	Renewable Biomass Fairness Act	Create Jobs Act	PECPA - Practical Energy and Climate Plan Act - Lugar
Year	2009	2009			2009	2009	2009	2010
Reference	S. 1733	S. 636 Introduced - Thune	S. 2364 Introduced DeFazio	S. 536 Introduced Wyden	H.R. 2227 introduced	H.R. 4374 Introduced	S. 2826 Introduced	S. 1462 Introduced
Purpose	Provides for the establishment of a cap and trade system for greenhouse gas (GHG) emission allowances and sets goals of reducing U.S. emissions by 20% by 2020 and by 83% by 2050.	Redefine Renewable Biomass to agree with 2002 Farm Security and Reform Act	Revised the definition of "renewable biomass" to include pre-commercial thinnings, or removed invasive species from National Forest System land and public lands	Revise the definition of "renewable biomass" to included limited harvest from National Foresty and land adjacent to public facilities at risk of fire	Revise the definition of "renewable biomass" to include trees, tree residue, and slash & pre-commerical thinnings from public lands	Amend the tax code of 1986 ot extend credit for electricity produced from biomass?	Amend Tax code to extend renewable production credit for open-loop biomass facilities	Legislation to limit greenhouse gas emissions and sets Diversified Energy Standards of 50% by 2050

Appendix B - Biomass Definition Spectrum

Scenario A
Focus primarily on "waste" or unused woody biomass
"Protect sensitive lands and prevent widespread land conversion"
Most strict interpretation of what is sensitive
Restrict biomass removal on natural stands whether they are sensitive or not
Restrictions on commercial vs pre-commercial
Restrictions on conversion of land

Exclusions	Inclusions
Federal Land	Plant and Byproducts
Critically Imperiled	Slash and Brush from Land Clearing
Late Success/Old Growth	Logging Residuals from Actively Managed Plantations
Commercial Thinning Operations	Biomass Operation on Designated Energy Crop
Logging residues from Naturally Regenerated Stands	Salvage from Fire, Insect and Disease
Converted Ag Land	
Biomass Operation on Active Managed Plantations	

Scenario B
Less strict interpretation of what is sensitve but basically the same intent as A
Allow biomass removal on non-sensitive natural stands
Restrictions on commercial vs pre-commercial
Restrictions on conversion of land

Exclusions	Inclusions
Federal Land	Plant and Byproducts
Critically Imperiled	Slash and Brush from Land Clearing
Late Success/Old Growth	Logging Residuals from Actively Managed Plantations
Commercial Thinning Operations	Biomass Operation on Designated Energy Crop
Converted Ag Land	Salvage from Fire, Insect and Disease
Biomass Operation on Active Managed Plantations	Logging residues from Naturally Regenerated Stands

Scenario C
Distinction between pulpwood roundwood sources and biomass fuel sources such that it restricts competition on traditional markets

Exclusions	Inclusions
Federal Land	Slash and Brush from Land Clearing
Critically Imperiled	Logging Residuals from Actively Managed Plantations
Late Success/Old Growth	Logging residues from Naturally Regenerated Stands
Commercial Thinning Operations	Biomass Operation on Designated Energy Crop
Converted Ag Land	Biomass Operation on Active Managed Plantations
	Salvage from Fire, Insect and Disease

Appendix B - Biomass Definition Spectrum (Continued)

Scenario	Exclusions	Inclusions
Scenario D **No distinction between pulpwood roundwood sources and biomass fuel sources**		
	Exclusions	**Inclusions**
	Federal Land	Plant and Byproducts
	Critically Imperiled	Slash and Brush from Land Clearing
	Late Success/Old Growth	Logging Residuals from Actively Managed Plantations
	Converted Ag Land	Logging residues from Naturally Regenerated Stands
		Biomass Operation on Designated Energy Crop
		Biomass Operation on Active Managed Plantations
		Commercial Thinning Operations
Scenario E **Allows for conversion of ag land with no limit**		
	Exclusions	**Inclusions**
	Federal Land	Plant and Byproducts
	Critically Imperilled	Slash and Brush from Land Clearing
	Late Success/Old Growth	Logging Residuals from Actively Managed Plantations
		Logging residues from Naturally Regenerated Stands
		Biomass Operation on Designated Energy Crop
		Biomass Operation on Active Managed Plantations
		Commercial Thinning Operations
		Salvage from Fire, Insect and Disease
		Converted Ag Land
Scenario F **Allows for limited harvest on Federal Lands**		
	Exclusions	**Inclusions**
	Federal Land -	Plant and Byproducts
	Critically Imperilled	Slash and Brush from Land Clearing
	Late Success/Old Growth	Logging Residuals from Actively Managed Plantations
		Logging residues from Naturally Regenerated Stands
		Biomass Operation on Designated Energy Crop
		Biomass Operation on Active Managed Plantations
		Commercial Thinning Operations
		Salvage from Fire, Insect and Disease
		Converted Ag Land
		Federal Lands - Fuel Reduction, Slash & Brush Removals, Salvage and Logging Residuals

Appendix J. Biomass Estimation in the FIADB

In previous versions of the FIADB, a variety of regional methods were used to estimate tree biomass for live and dead trees in the TREE table. In FIADB 4.0, a new nationally consistent method of estimating tree biomass has been implemented. This new approach, called the component ratio method (CRM) (Heath and others 2009), involves calculating the dry weight of individual components before estimating the total aboveground or belowground biomass. The CRM approach is based on:

- converting the sound volume of wood (VOLCFSND) in the merchantable bole to biomass using a compiled set of wood specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of bark on the merchantable bole using a compiled set of percent bark estimates and bark specific gravities (Miles and Smith 2009) (see REF_SPECIES table for values)
- calculating the biomass of the entire tree (total aboveground biomass), merchantable bole outside bark, and belowground biomass using equations from Jenkins and others (2003)
- calculating the volume of the stump (wood and bark) based on equations in Raile (1982) and converting this to biomass using the same specific gravities used for the bole wood and bark
- calculating the top biomass (tree tip and all branches) by subtracting all other biomass components from the total aboveground estimate
- calculating an adjustment factor by developing a ratio between bole biomass from VOLCFSND to bole biomass from Jenkins and others (2003)
- applying the adjustment factor to all tree components derived from both Jenkins and Raile

The CRM approach is based on assumptions that the definition of merchantable bole in the volume prediction equations is equivalent to the bole (stem wood) in Jenkins and others (2003), and that the component ratios accurately apply.

The tables in this appendix describe the equations used in FIADB 4.0 to estimate components of tree biomass, including stem wood (bole), top and branches combined, bark, stump, and coarse roots. Most of these components are estimated through a series of ratio equations as described by Jenkins and others (2003). Stem wood biomass is calculated directly from the sound cubic-foot volume of the tree bole, percentage of bark on the bole, and specific gravities of both wood and bark.

Note that component equations are not available for woodland tree species or for saplings because saplings have no volume in FIADB. Because of this, only total aboveground biomass is estimated for saplings (trees from 1 to 4.9 inches in diameter) and woodland species [trees where diameter is measured at the root collar (DRC)]. The individual component biomass values for bole, top, and stump are not available in FIADB. Volume equations for woodland species include all wood and bark from ground to tip. When converted to biomass, the result is total aboveground biomass excluding foliage for these species. Belowground biomass is estimated for all trees greater than or equal to 1 inch.

Definitions of each biomass component and the equations used to estimate the ovendry weight in pounds are shown in appendix tables J-1 through J-5.

- Appendix table J-1 defines the columns that are stored in the TREE table, and clarifies the set of trees (species, dimensions, live or dead, etc) that are used in each calculation.

- Appendix table J-2 defines the Jenkins component equations and explains how the equation results are used to estimate biomass. The 'Estimate name' in this table is the same name found in the coefficient definitions described in the biomass-related columns 38 to 49 of the REF_SPECIES table.

- Appendix table J-3 contains the Jenkins equations used to estimate each biomass component. The equations use the exact coefficient column names found in the REF_SPECIES table (for example, JENKINS_TOTAL_B1 in appendix table J-3 is the column name in REF_SPECIES that holds the value of the coefficient needed in the total aboveground biomass equation). The Jenkins equations use the measured tree diameter to produce an estimate.

- Appendix table J-4 contains the actual equations used in the FIADB to estimate the biomass components stored in the TREE table. These equations are a blend of Jenkins ratios, calculated bole biomass (based on calculated volume from the TREE table), and adjustment factors. The adjustment factor is an important step because it relates measurement-based bole biomass (DRYBIO_BOLE) to generalized equation-based bole biomass to improve or adjust the computed results of the Jenkins equations.

- Appendix table J-5 contains equations that show the approach described by Heath and others (2009), where the proportion of the biomass component relative to stem volume is calculated first, and then is applied to DRYBIO_BOLE to develop the final estimate in pounds.

For more information please consult the publication by Heath and others (2009), titled *Investigation into calculating tree biomass and carbon in the FIADB using a biomass expansion factor approach*.

Appendix table J-1. Definition of Biomass Components stored in the TREE table

Component	**Column name**	**Biomass Component Definition (all are ovendry biomass, pounds)**
Merchantable stem (bole)	DRYBIO_BOLE	Merchantable bole of the tree, includes stem wood and bark, from a 1-foot stump to a 4-inch top diameter outside bark (DOB). Based on VOLCFSND and specific gravity for the species. For timber species with a DIA ≥ 5 inches DBH. Includes live and dead trees. (note that VOLCFGRS or VOLCFNET might be used after adjustment based on national averages, if VOLCFSND is not available)
Top	DRYBIO_TOP	Top of the tree above 4 inches DOB and all branches; includes wood and bark and excludes foliage. For timber species with a DIA ≥ 5 inches DBH. Includes live and dead trees.
Stump	DRYBIO_STUMP	Stump of the tree, the portion of a tree bole from ground to 1 foot high, includes wood and bark. For timber species with a DIA ≥ 5 inches DBH. Includes live and dead trees.
Belowground	DRYBIO_BG	Coarse roots of trees and saplings with a DIA ≥ 1 inch DBH or DRC. Includes timber and woodland species, and live and dead trees.
Saplings	DRYBIO_SAPLING	Total aboveground portion of live trees, excluding foliage. For timber species with a DIA ≥ 1 inch and less than 5 inches DBH.
Woodland tree species	DRYBIO_WDLD_SPP	Total aboveground portion of tree, excluding foliage. For woodland species with a DIA ≥ 1 inch DRC. Includes live and dead trees. Woodland species can be identified by REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, or TREE.WDLDSTEM > 0

Appendix table J-2. Jenkins Biomass Component Equation Definitions
(Refer to the REF_SPECIES table for equation coefficients and adjustment factors)

Component	**Estimate name**	**Definition**
Total aboveground biomass	total_AG_biomass_ Jenkins	Total biomass of the aboveground portion of a tree. Includes stem wood, stump, bark, top, branches, and foliage. (ovendry biomass, pounds)
Stem wood biomass ratio	stem_ratio	A ratio that estimates biomass of the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins. Includes wood only. This is the portion of the tree from a 1-foot stump to a 4-inch top DOB.
Stem bark biomass ratio	bark_ratio	A ratio that estimates biomass of the bark on the merchantable bole of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Foliage biomass ratio	foliage_ratio	A ratio that estimates biomass of the foliage on the entire tree, by applying the ratio to total_AG_biomass_Jenkins.
Coarse root biomass ratio	root_ratio	A ratio that estimates biomass of the belowground portion of the tree, by applying the ratio to total_AG_biomass_Jenkins.
Stump biomass	stump_biomass	An estimate of the stump biomass of a tree, from the ground to 1 foot high. Uses a series of equations that estimate first the diameter inside and outside bark, followed by volume inside and outside bark developed by Raile (1982). Wood and bark volumes are converted to biomass using specific gravity for the species.
Sapling biomass adjustment	JENKINS_SAPLING _ADJUSTMENT	An adjustment factor that is used to estimate sapling biomass for the tree, by applying the factor to the total aboveground estimate excluding foliage. The adjustment factor was computed as a national average ratio of the DRYBIOT (total dry biomass) divided by the Jenkins total biomass for all 5.0-inch trees, which is the size at which biomass based on volume begins.

Appendix table J-3. Jenkins Biomass Equations (Actual B1 and B2 coefficients and adjustment factors are stored in the REF_SPECIES table.) Note: these equations are used in appendix table J-4 to estimate the biomass components stored in the TREE table.

Component	**Equation**
total_AG_biomass_Jenkins (pounds) (total aboveground biomass, includes wood and bark for stump, bole, top, branches, and foliage)	= exp(JENKINS_TOTAL_B1 + JENKINS_TOTAL_B2 * ln(DIA*2.54)) * 2.2046
stem_ratio	= exp(JENKINS_STEM_WOOD_RATIO_B1 + JENKINS_STEM_WOOD_RATIO_B2 / (DIA*2.54))
bark_ratio	= exp(JENKINS_STEM_BARK_RATIO_B1 + JENKINS_STEM_BARK_RATIO_B2 / (DIA*2.54))
foliage_ratio	= exp(JENKINS_FOLIAGE_RATIO_B1 + JENKINS_FOLIAGE_RATIO_B2 / (DIA*2.54))
root_ratio	= exp(JENKINS_ROOT_RATIO_B1 + JENKINS_ROOT_RATIO_B2 / (DIA*2.54))
stem_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * stem_ratio
bark_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * bark_ratio
bole_biomass_Jenkins (pounds)	= stem_biomass_Jenkins + bark_ biomass_Jenkins
foliage_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * foliage_ratio
root_biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins * root_ratio
stump_biomass (pounds)	Volumes of wood and bark are based on diameter inside bark (DIB) and DOB equations from Raile, 1982. DIB = (DIA * RAILE_STUMP_DIB_B1) + (DIA * RAILE_STUMP_DIB_B2 * (4.5-HT) / (HT+1)) DOB = DIA + (DIA * RAILE_STUMP_DOB_B1 * (4.5-HT) / (HT+1)) Volume is estimated for 0.1ft (HT) slices from ground to 1 foot high (HT), and summed to compute stump volume. Bark_volume = Volume_outside_bark – Volume_inside_bark Bark and wood volumes are multiplied by their respective specific gravities and added together to estimate biomass
top biomass_Jenkins (pounds)	= total_AG_biomass_Jenkins – stem_biomass – bark_biomass – foliage_biomass – stump_biomass

Appendix table J-4. Equations used to calculate Biomass Components stored in the TREE table

Column name	**Equation (refer to Appendix J-3 for details on variables found in equations below)**
	AdjFac = DRYBIO_BOLE / bole_biomass_Jenkins **AdjFac_woodland** = DRYBIO_BOLE / (total_AG_biomass_Jenkins – foliage_biomass_Jenkins)
DRYBIO_BOLE (wood and bark) (see note below)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4)) Note: For woodland species, volume equations produce volume outside bark, from ground to tip including branches, therefore DRYBIO_BOLE is the biomass from ground to tip. Wood and bark volumes need to be estimated before converting to biomass as follows: = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + ((VOLUME – (VOLUME * (BARK_VOL_PCT/100.0))) * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
DRYBIO_TOP	= top_biomass_Jenkins * **AdjFac**
DRYBIO_STUMP	= stump_biomass * **AdjFac**
DRYBIO_SAPLING	= (total_AG_biomass_Jenkins – foliage_biomass_Jenkins) * JENKINS_SAPLING_ADJUSTMENT
DRYBIO_WDLD_SPP	= DRYBIO_BOLE (trees>= 5 inches DIA_) = DRYBIO_SAPLING (trees < 5 inches DIA) For tree species where REF_SPECIES.WOODLAND = X, TREE.DIAHTCD = 2, and/or TREE.WDLDSTEM > 0 Note: volume equations produce volume from ground to tip, including branches; DRYBIO_BOLE is the biomass of all wood from ground to tip
DRYBIO_BG	= root_biomass_Jenkins * **AdjFac** (for timber spp >= 5 inches DIA) = root_biomass_Jenkins * **AdjFac_woodland** (for woodland spp >= 5 inches DIA) = root_biomass_Jenkins * JENKINS_SAPLING_ADJUSTMENT (for all trees < 5 inches DIA)
Note: If DIA >= 5.0 and VOLCFSND > 0 then VOLUME = VOLCFSND If DIA >= 5.0 and VOLCFSND = (0 or null) and VOLCFGRS > 0 then VOLUME = VOLCFGRS * Percent Sound If DIA >= 5.0 and VOLCFSND and VOLCFGRS = (0 or null) then VOLUME = VOLCFNET * (Ratio of cubic foot sound to cubic foot net vol)	

Appendix table J-5. Alternative method to calculate Biomass Components, following Heath and others, 2009

Component	Equation
DRYBIO_BOLE (wood and bark)	VOLUME = VOLCFSND (or VOLCFRS, VOLCFNET that are adjusted for the percent sound) = (VOLUME * (BARK_VOL_PCT/100.0) * (BARK_SPGR_GREENVOL_DRYWT * 62.4)) + (VOLUME * (WOOD_SPGR_GREENVOL_DRYWT * 62.4))
TOP_proportion	= top_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_TOP	= TOP_proportion * DRYBIO_BOLE
STUMP_proportion	= stump_biomass / bole_biomass_ Jenkins
DRYBIO_STUMP	= STUMP_proportion * DRYBIO_BOLE
BG_proportion	= root_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BG	= BG_proportion * DRYBIO_BOLE
BARK_proportion	= bark_biomass_Jenkins / bole_biomass_ Jenkins
DRYBIO_BARK	= BARK_proportion * DRYBIO_BOLE

Appendix D - FIA Biomass Database Data Listing

Data Field	Description
Compil_Yr	Date assigned as the effective year of compilation for a state
Statecd	State ID
St_abbr	State Name
Unitcd	FIA Unit ID
Unit_Name	FIA Unit Name
Agric_LU	FIA Agricultural Land Use
ALSTKCD	All live stocking code. A code indicating the stocking of the condition by live trees, including seedlings.
Siteclcd	Site productivity class code. A classification of forest land in terms of inherent capacity to grow crops of industrial wood. Identifies the potential growth in cubic feet/acre/year and is based on the culmination of mean annual increment of fully stocked natural stands. For data stored in the database that were processed outside of NIMS, this variable may be assigned based on the site productivity determined with the site trees, or from some other source, but the actual source of the site productivity class code is not known. For data processed with NIMS, this variable may either be assigned based on the site trees available for the plot, or, if no valid site trees are available, this variable is set equal to SITECLCDEST, a default value that is either an estimated or predicted site productivity class. If SITECLCDEST is used to populate SITECLCD, the variable SITECL_METHOD is set to 6.
Owner	FIA Owner Type
Mgt_type	FIA Forest Management Type
Damaged	FIA Damage Observation Code
Agecls	FIA 5 year age class
Rec_type	Record Type
Understory_bio_sum	Understory_bio_sum--estimated biomass (in Tons) of understory components (seedlings, shrubs, brush) aboveground. Derived from Carbon_understory_AG variable, which is in tons/acre in Condition table of FIADB4.0. This variable is estimated from models based on region, forest type and live tree carbon density (Smith and Health 2008). Understory biomass values at the population level were computed as follows: Understory_bio = Carbon_understory_AG * 2 * Condition Acres
Acreage	Sum of Condition level acreage
SppGrp	FIA Major Specie Group
Tree_class	FIA Treel Classification
D.b.h._class	FIA 1 Inch Diameter Classes
Mervolsum	Sum of net merchantable volume in cubic feet (1 foot stump to 4 inch top bole diameter). This is the traditional FIA volume variable. Select TreeClass=2 and sum Mervolsum to obtain Growing-stock Volume. Include TreeClass 2 and 3 for All Live merchantable volume.
Sawcfsum	Sum of net volume of saw-log section in cubic feet. This is a subset of Mervolsum. Only populated for growing stock trees of sawtimber size.
Bolewtsum	Sum of dry weight of the merchantable bole in tons.
Sawwtsum	Sum of dry weight of the saw-log section in tons.
Upstemwtsum	Sum of dry weight (tons) in the upper stem (saw-log top to 4.0 inch bole diameter) of sawtimber trees.
Topwtsum	Sum of dry weight (tons) in the top of trees 5.0 inches d.b.h. and larger. Includes bole from 4.0 inch top diameter to tip and all branches. Does not include foliage.
Stumpwtsum	Sum of dry weight (tons) in the stump (ground level to 1.0 foot above ground) of trees 5.0 inches d.b.h. and larger.
Sapwtsum	Sum of dry weight (tons) of trees 1.0--4.9 inches d.b.h.

Appendix E - Total Biomass Estimate by Supply Bucket - FIA Biomass Database

Detail Supply Bucket	Alabama	Arkansas	Florida	Georgia	Kentucky	Louisiana	Mississippi	North Carolina	Oklahoma	South Carolina	Tennessee	Texas	Virginia	Total
Plant Residue	6,260,000	4,949,000	2,786,000	6,895,000	1,506,000	4,893,000	5,258,000	4,901,000	887,000	2,934,000	1,976,000	2,799,000	2,920,000	48,964,000
Slash & Brush From Non-Damaged Stands	50,779,195	34,886,222	26,118,629	50,605,975	22,839,527	26,177,832	38,060,521	33,474,550	9,562,629	26,833,259	24,569,916	26,177,832	27,636,513	397,722,600
Logging Residue from Planted Stands - Merchantable	36,450,888	16,325,691	25,242,166	43,151,313	458,169	19,595,893	30,852,615	21,376,107	2,826,862	23,161,276	3,566,570	19,595,893	21,522,402	264,125,844
Logging Residue from Natural Stands - Merchantable	157,017,471	136,689,094	56,686,284	169,878,917	133,039,786	80,644,304	120,983,772	151,686,138	25,964,666	95,918,252	142,296,383	80,644,304	133,673,526	1,485,122,896
Logging Residue from Planted Stands - Premerchantable	10,046,646	2,902,893	5,630,865	10,210,513	21,992	5,657,571	5,194,950	2,746,525	514,956	3,825,071	1,229,681	5,657,571	2,303,527	55,942,761
Logging Residue from Natural Stands - Premerchantable	12,708,654	3,020,373	2,022,856	10,547,851	1,219,824	4,709,371	7,483,258	7,817,464	882,497	7,041,266	3,228,284	4,709,371	5,709,528	71,100,599
Pulpwood from Planted Stands - Premerchantable	6,103,232	1,565,592	1,762,184	5,190,301	8,599	2,931,142	3,231,838	907,524	195,594	1,640,372	513,639	2,931,142	656,966	27,638,126
Pulpwood from Natural Stands Premerchantable	8,494,486	2,044,432	1,682,661	7,817,844	995,440	2,505,860	4,765,401	4,265,514	845,622	3,714,185	2,573,256	2,505,860	3,965,451	46,176,013
Pulpwood from Planted Stands - Merchantable	53,669,710	18,039,507	41,015,269	70,589,647	521,520	22,083,793	39,333,407	24,527,857	2,146,889	33,823,842	5,179,893	22,083,793	26,956,922	359,972,049
Pulpwood from Natural Stands - Merchantable	156,297,542	137,154,168	70,257,588	175,820,201	151,604,324	74,243,883	119,246,536	145,638,834	32,228,584	95,605,479	164,179,758	74,243,883	148,112,734	1,544,633,515
Sawtimber from Planted and Natural Stands - Premerchantable and Merchantable	243,120,120	209,331,757	74,848,005	270,196,042	174,445,511	169,684,556	200,442,732	236,443,884	23,679,726	152,847,315	197,329,286	169,684,556	199,004,999	2,321,058,488
Salvage from Damaged Stands (Fire, Insect, Disease)	67,062,272	11,248,524	35,401,196	69,933,170	44,360,240	49,872,876	100,315,126	58,623,465	37,215,092	21,391,960	30,446,288	49,872,876	29,818,322	605,561,408
Volume in Stands >80 Undamaged	37,312,391	19,685,162	32,883,499	63,434,325	39,703,699	28,292,149	8,700,208	88,697,664	7,203,404	37,132,841	68,364,726	28,292,149	121,567,462	581,269,679
Total Supply	845,322,605	597,842,415	376,337,202	954,271,098	570,724,632	491,292,230	683,868,364	781,106,525	144,153,523	505,869,118	645,453,681	489,198,230	723,848,353	7,809,287,977

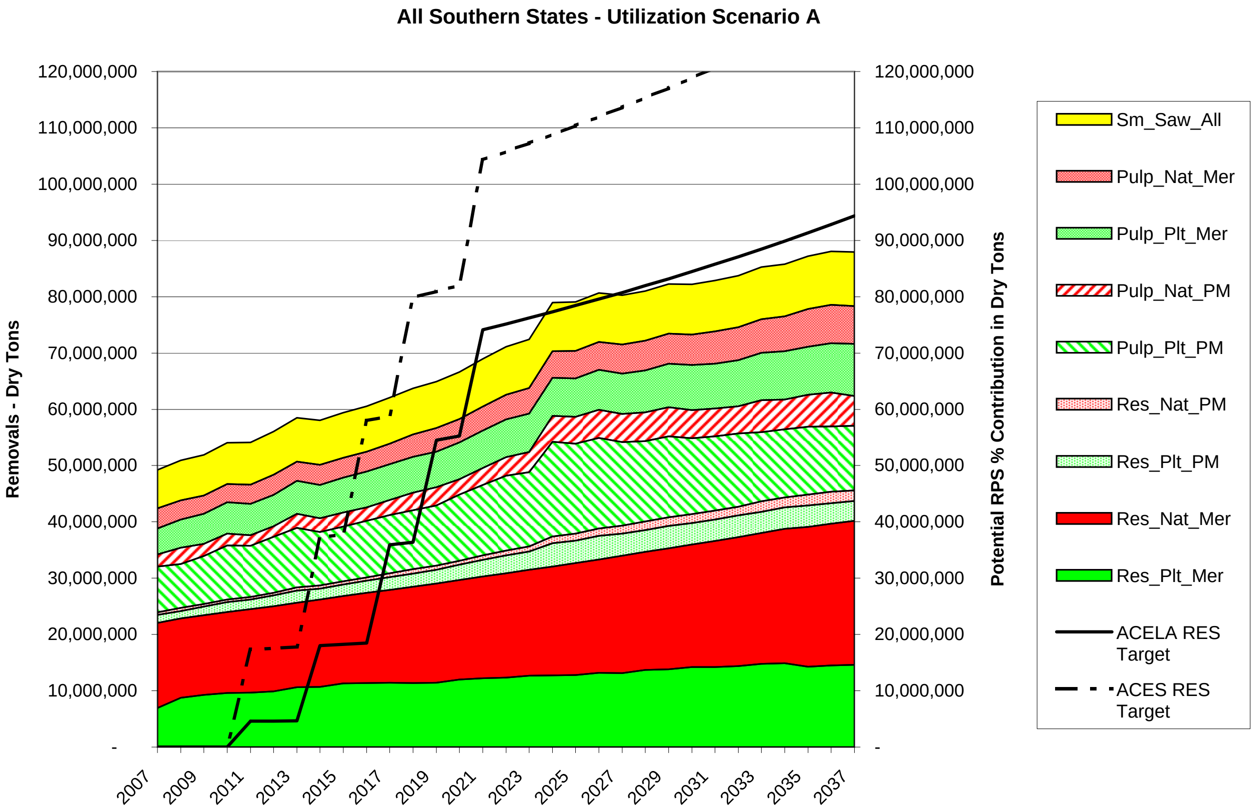
Summary Supply Bucket	Alabama	Arkansas	Florida	Georgia	Kentucky	Louisiana	Mississippi	North Carolina	Oklahoma	South Carolina	Tennessee	Texas	Virginia	Total
Plant Residue	6,260,000	4,949,000	2,786,000	6,895,000	1,506,000	4,893,000	5,258,000	4,901,000	887,000	2,934,000	1,976,000	2,799,000	2,920,000	48,964,000
Slash & Brush	50,779,195	34,886,222	26,118,629	50,605,975	22,839,527	26,177,832	38,060,521	33,474,550	9,562,629	26,833,259	24,569,916	26,177,832	27,636,513	397,722,600
Logging Residue	216,223,658	158,938,051	89,582,171	233,788,594	134,739,772	110,607,139	164,514,595	183,626,234	30,188,981	129,945,865	150,320,919	110,607,139	163,208,983	1,876,292,101
Pulpwood Inventory	224,564,969	158,803,699	114,717,703	259,417,993	153,129,884	101,764,678	166,577,181	175,339,728	35,416,690	134,783,878	172,446,546	101,764,678	179,692,074	1,978,419,702
Sawtimber Inventory	243,120,120	209,331,757	74,848,005	270,196,042	174,445,511	169,684,556	200,442,732	236,443,884	23,679,726	152,847,315	197,329,286	169,684,556	199,004,999	2,321,058,488
Salvage from Damaged Stands (Fire, Insect, Disease)	67,062,272	11,248,524	35,401,196	69,933,170	44,360,240	49,872,876	100,315,126	58,623,465	37,215,092	21,391,960	30,446,288	49,872,876	29,818,322	605,561,408
Volume in Stands >80 Undamaged	37,312,391	19,685,162	32,883,499	63,434,325	39,703,699	28,292,149	8,700,208	88,697,664	7,203,404	37,132,841	68,364,726	28,292,149	121,567,462	581,269,679
Total	845,322,605	597,842,415	376,337,202	954,271,098	570,724,632	491,292,230	683,868,364	781,106,525	144,153,523	505,869,118	645,453,681	489,198,230	723,848,353	7,809,287,977

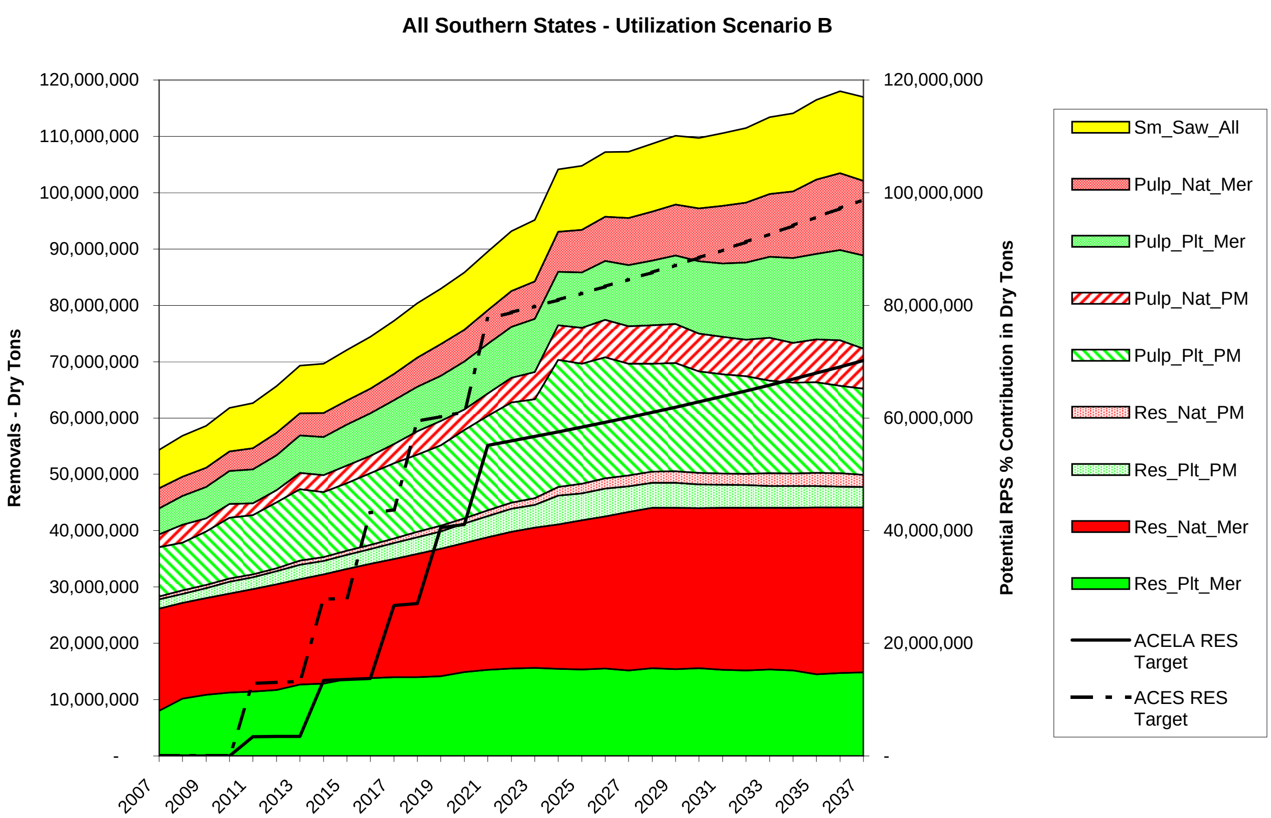
Appendix F - TPO Logging Residual Used in SRTS

State	Pine GS	Pine NGS	Hdwd GS	Hdwd NGS
Alabama	5%	13%	15%	22%
Arkansas	9%	18%	11%	25%
Florida	7%	12%	22%	30%
Georgia	6%	15%	23%	29%
Louisiana	5%	10%	24%	34%
Mississippi	5%	9%	19%	38%
North Carolina	9%	16%	14%	22%
Oklahoma	6%	18%	11%	21%
South Carolina	8%	19%	12%	30%
Tennessee	16%	36%	13%	19%
Texas	6%	13%	14%	26%
Virginia	10%	19%	16%	20%
Kentucky	7%	14%	15%	28%
Average	8%	16%	16%	27%

GS = Growing Stock
NGS= Non-Growing Stock

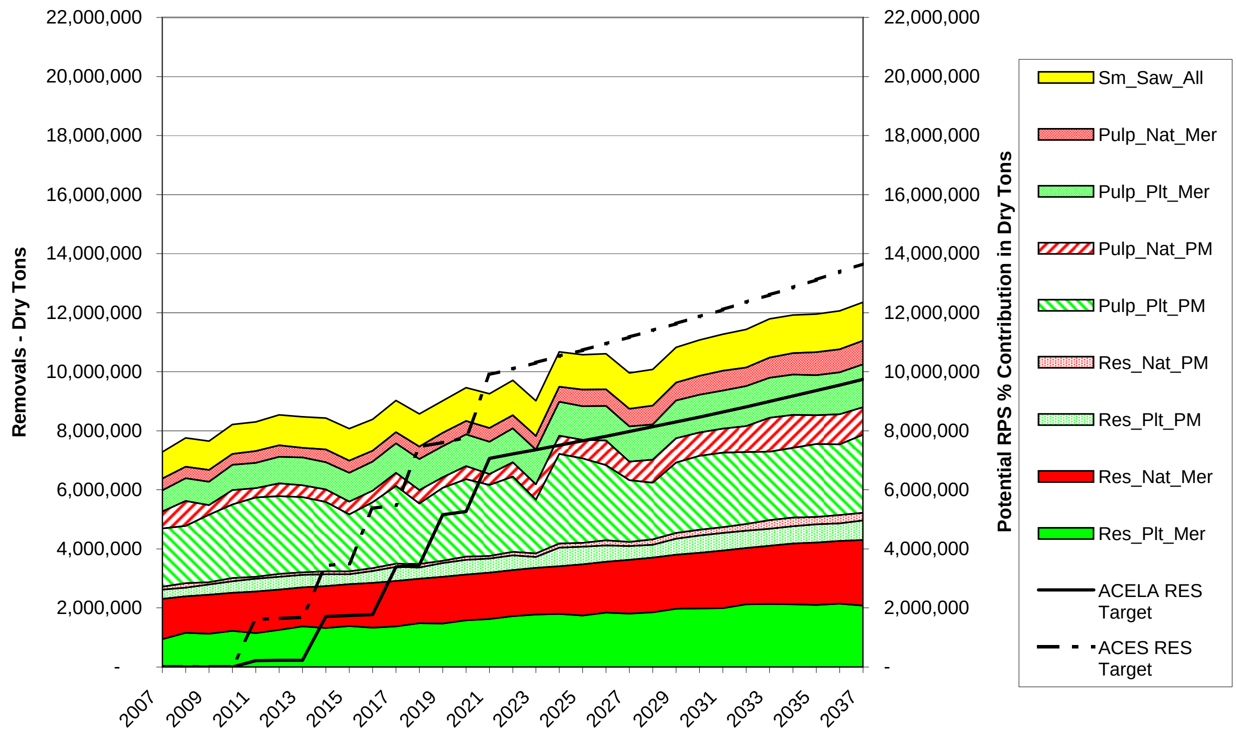
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



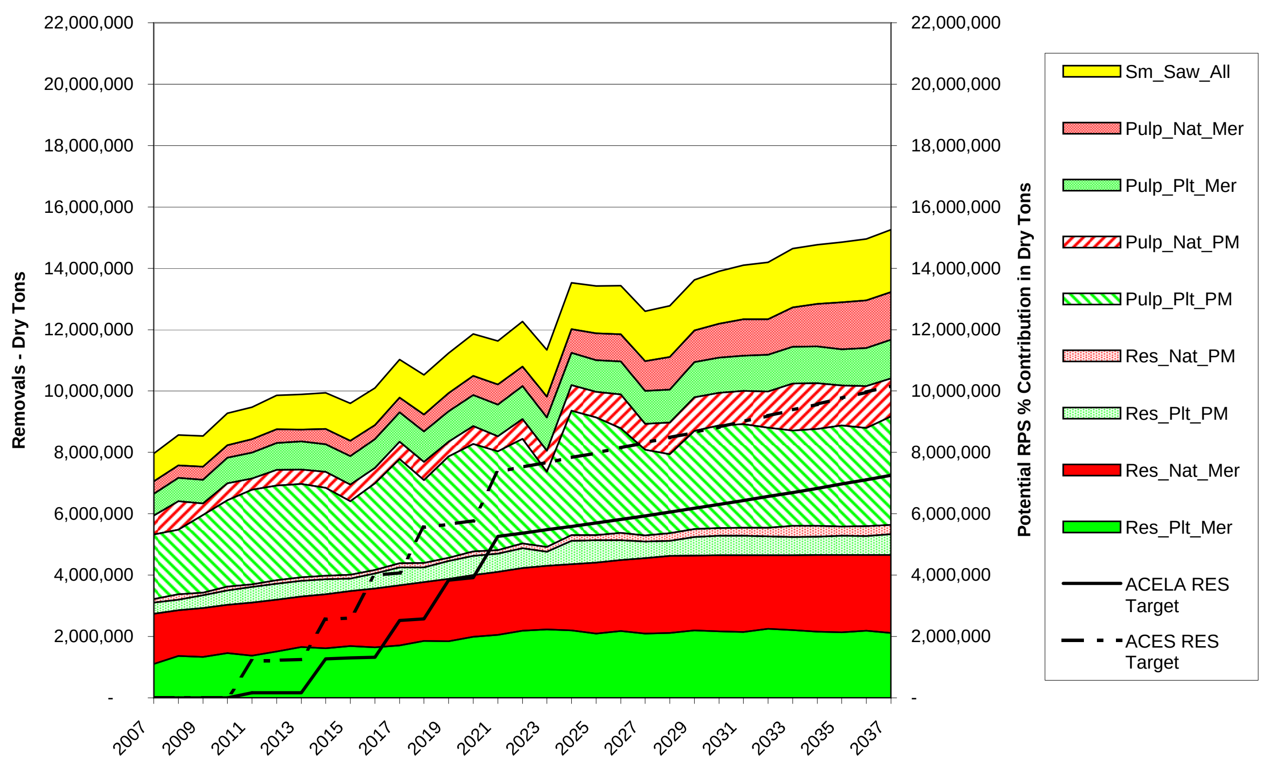


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

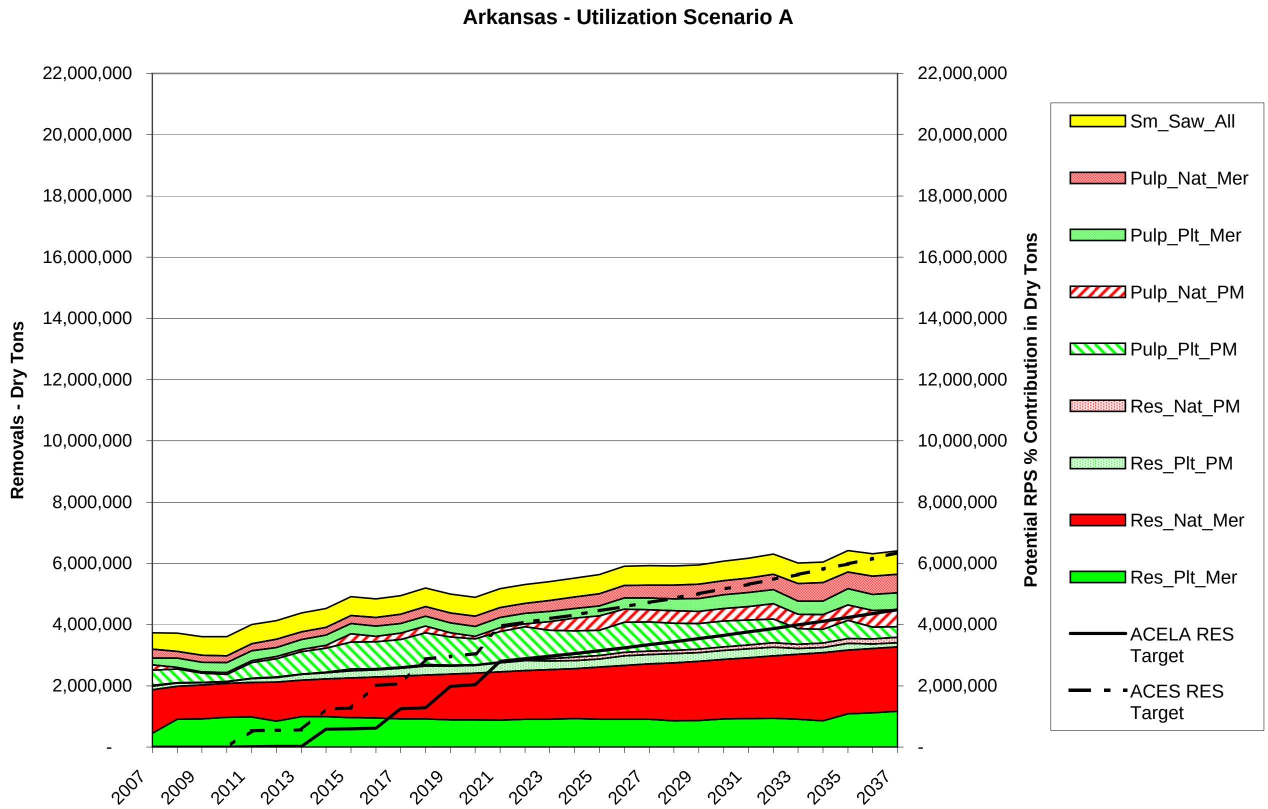
Alabama - Utilization Scenario A

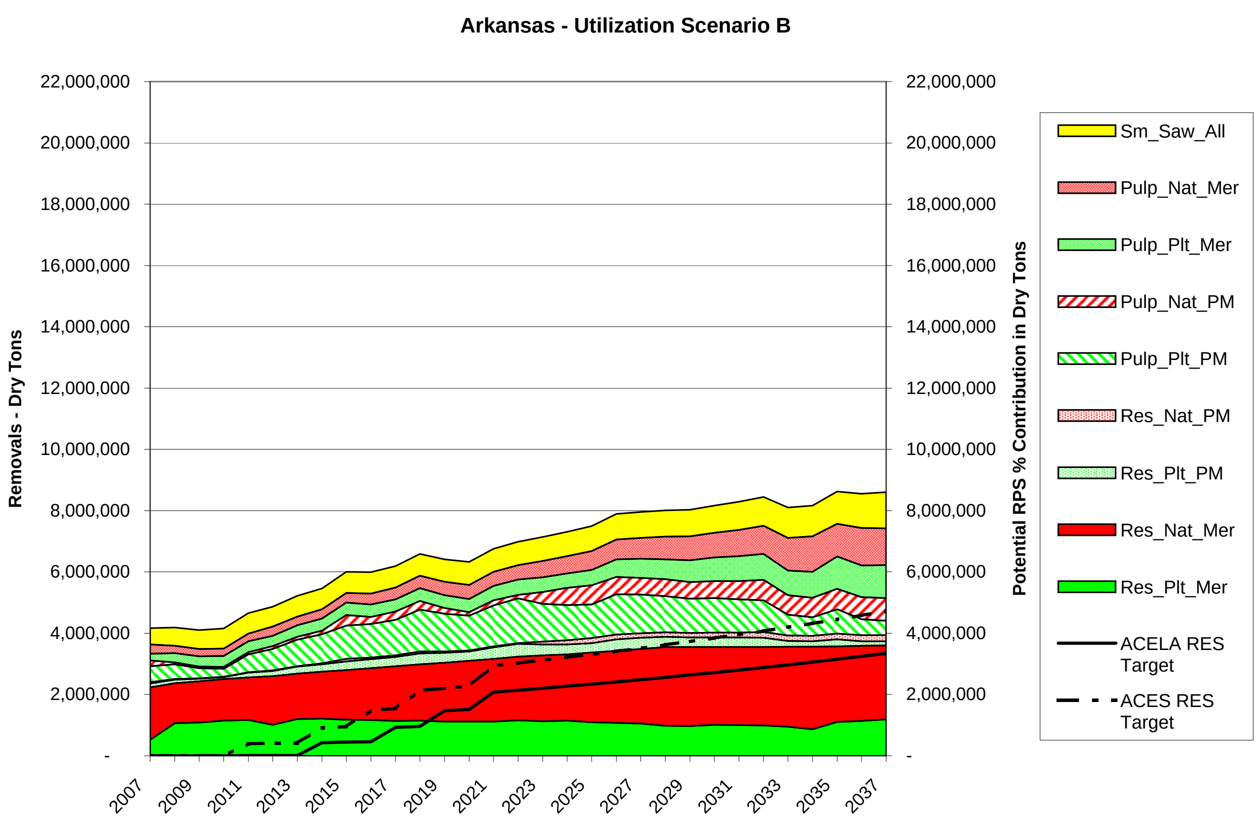


Alabama- Utilization Scenario B

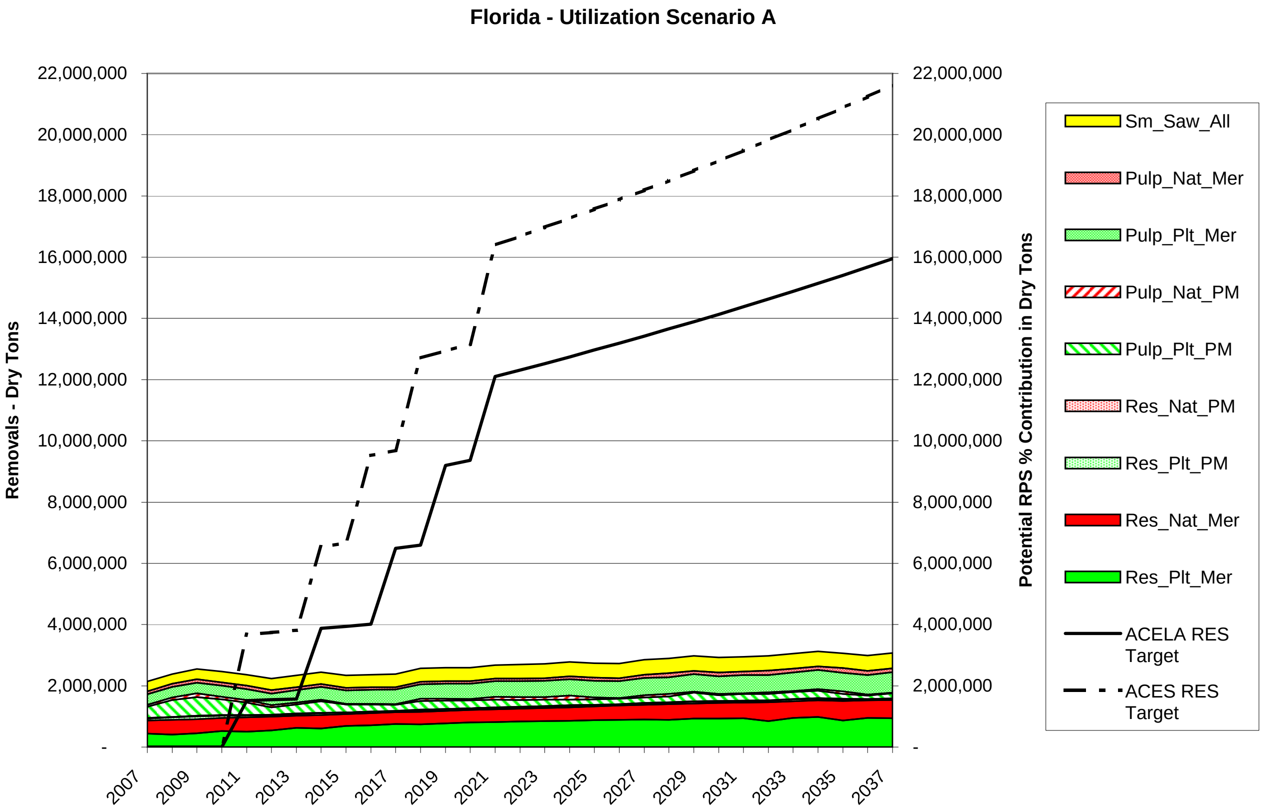


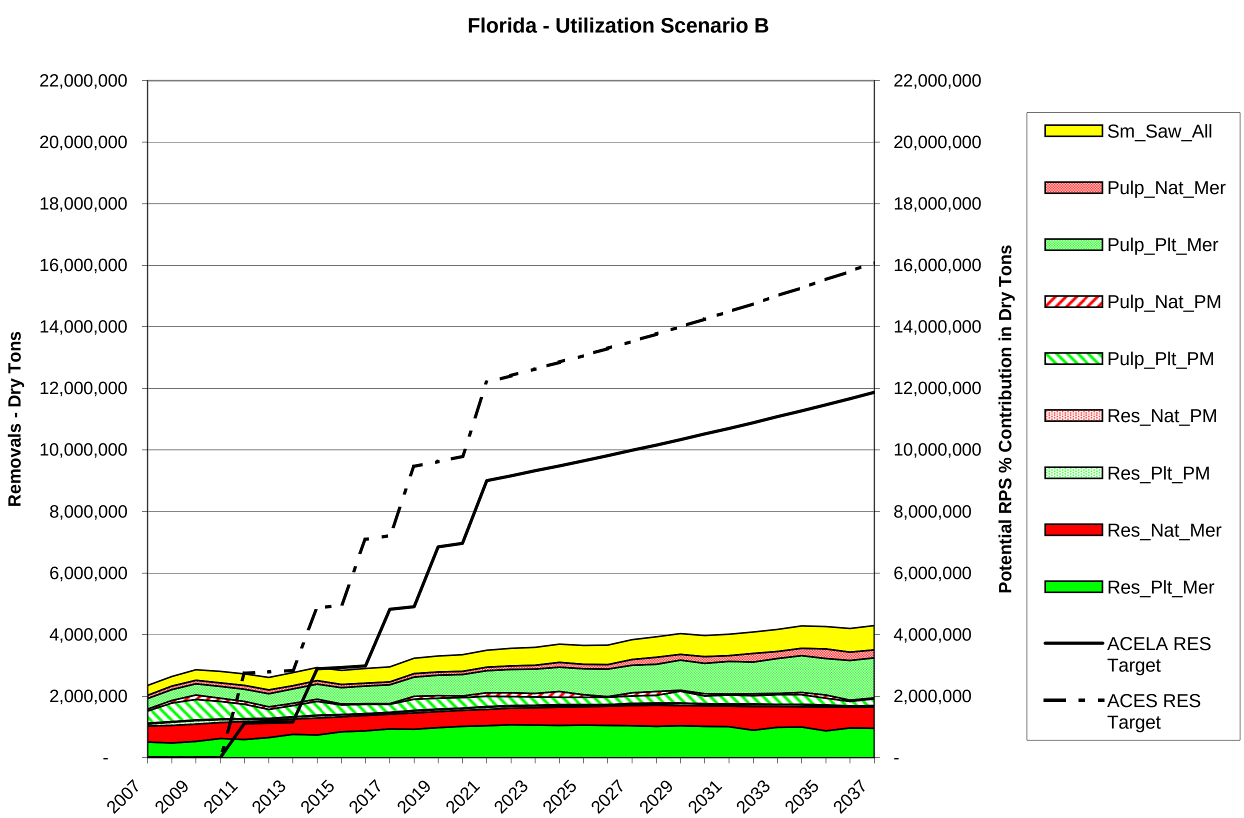
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



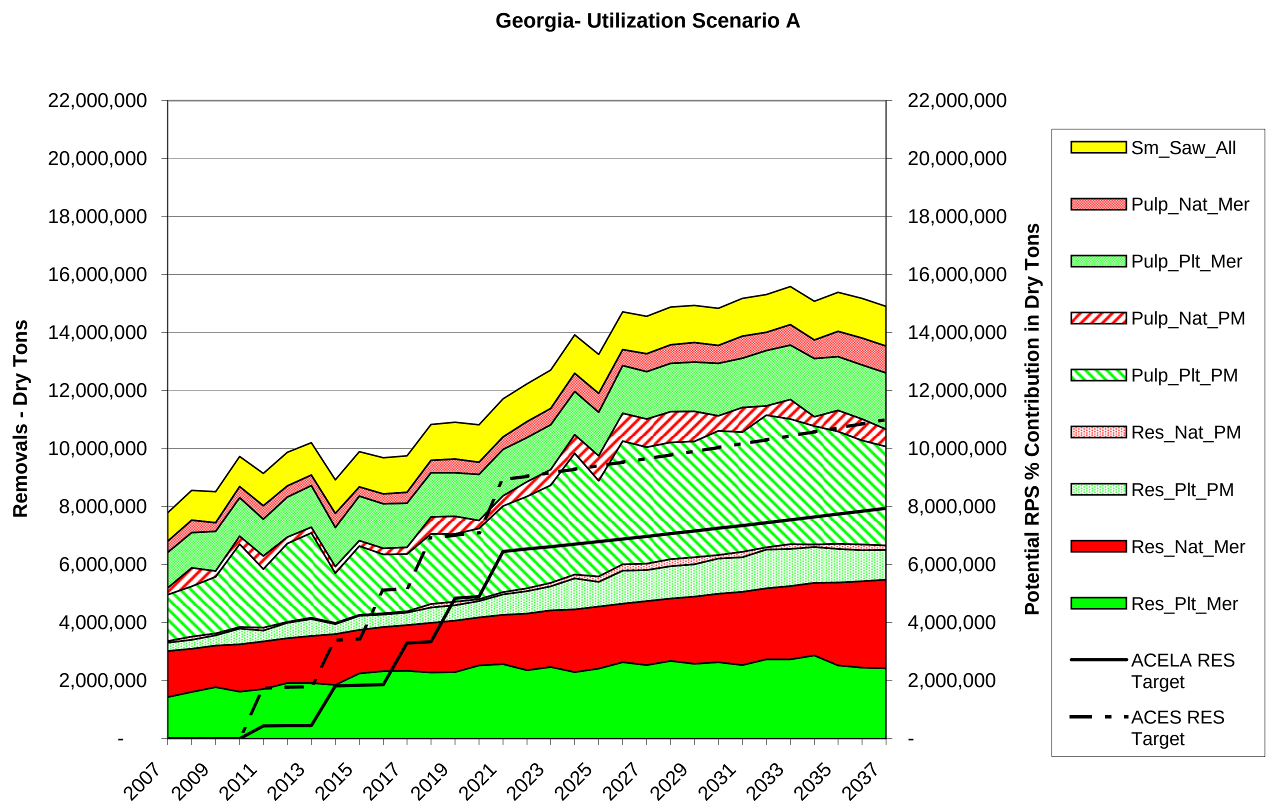


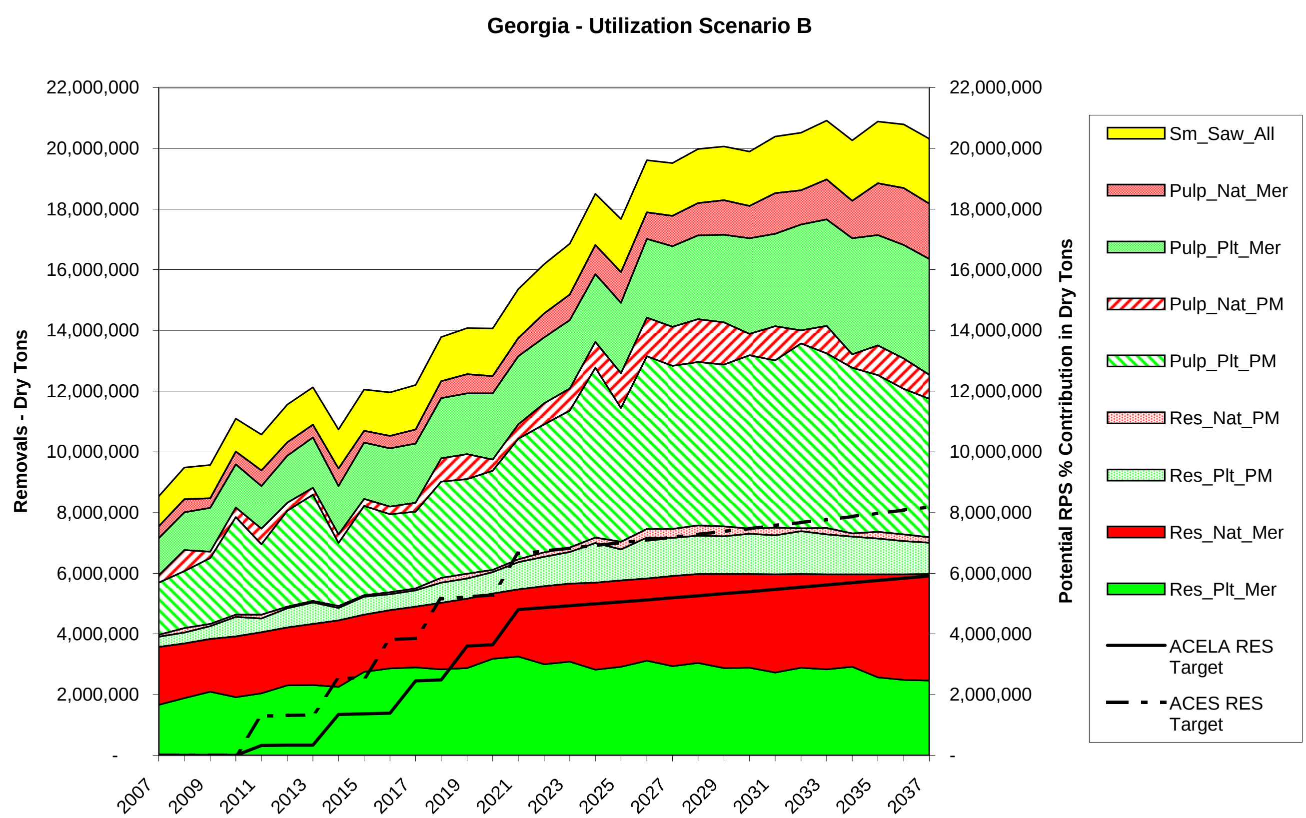
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)





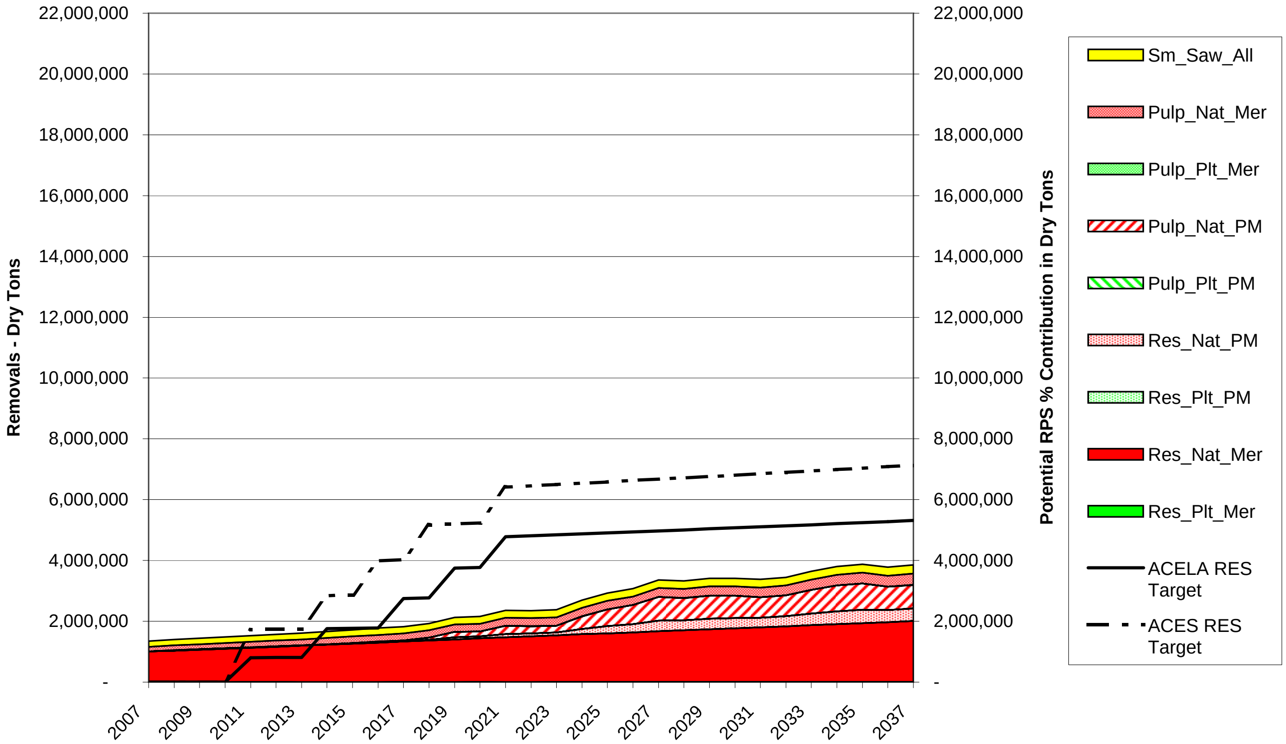
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



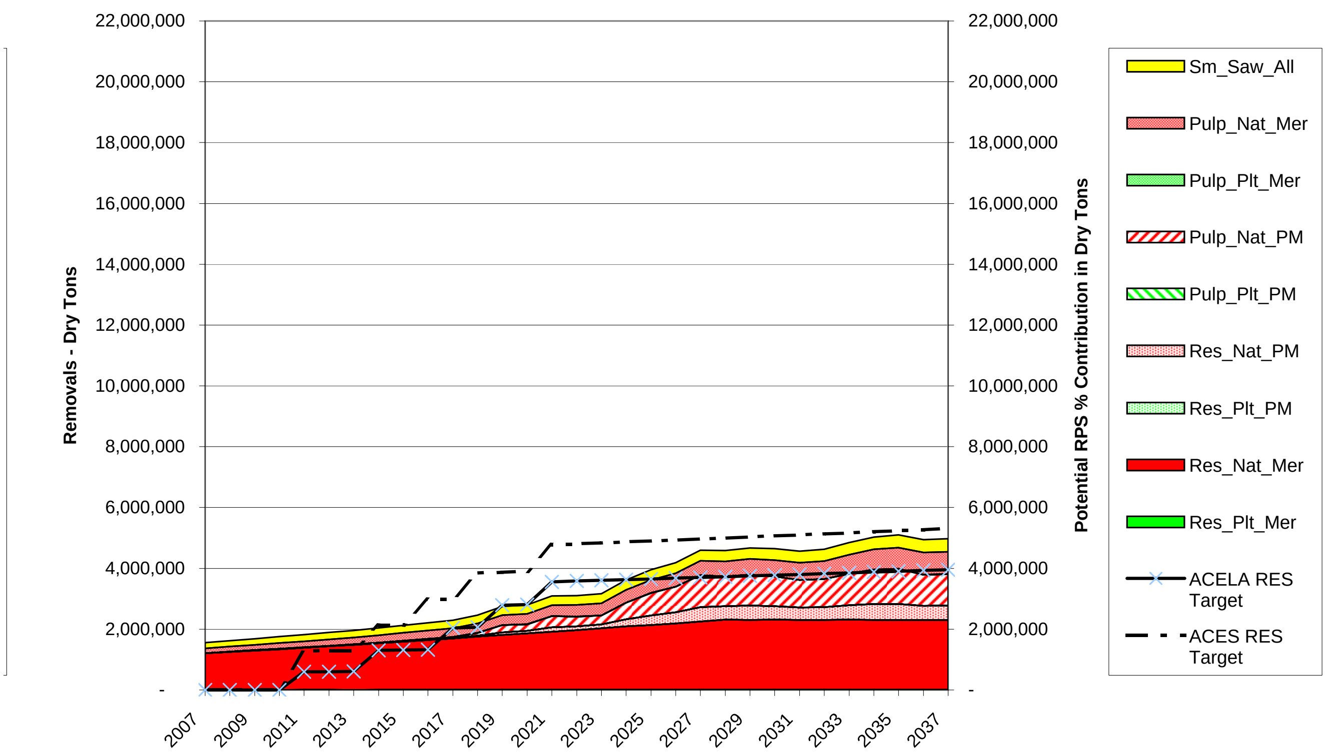


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

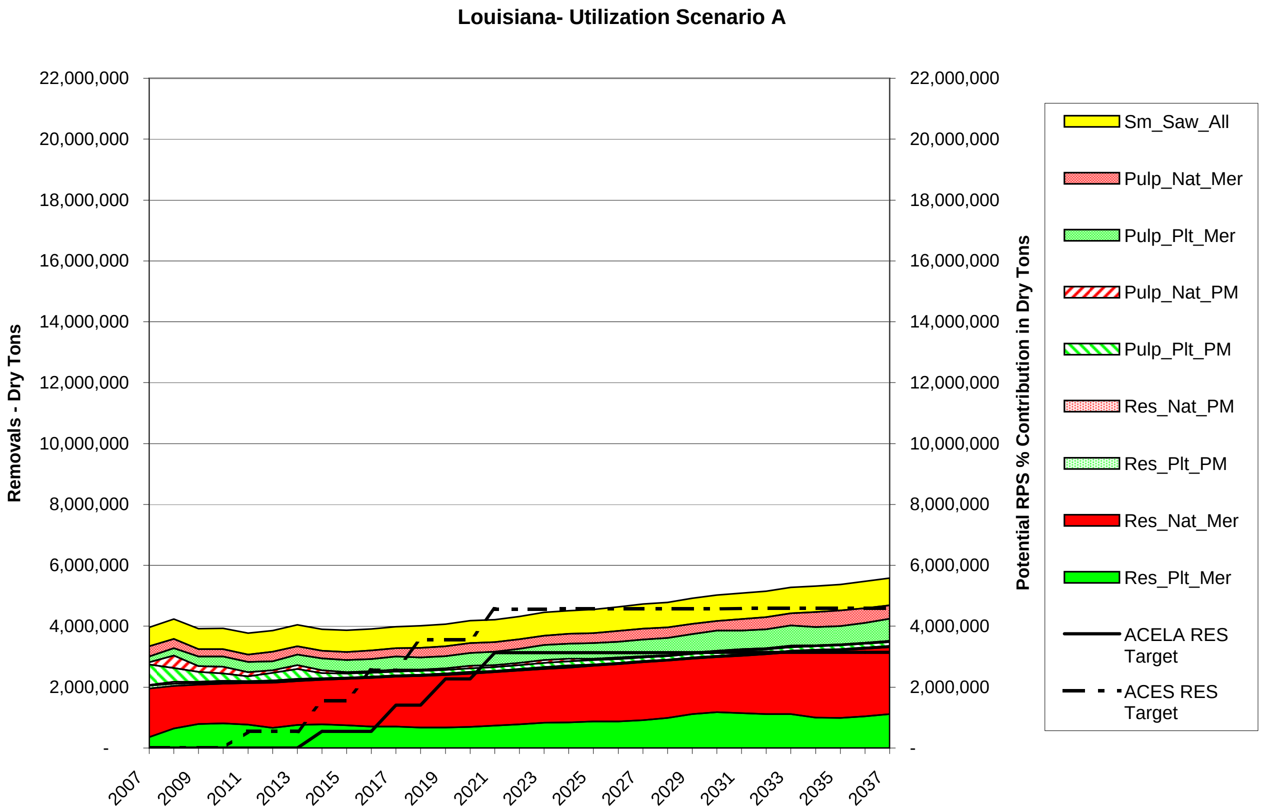
Kentucky - Utilization Scenario A

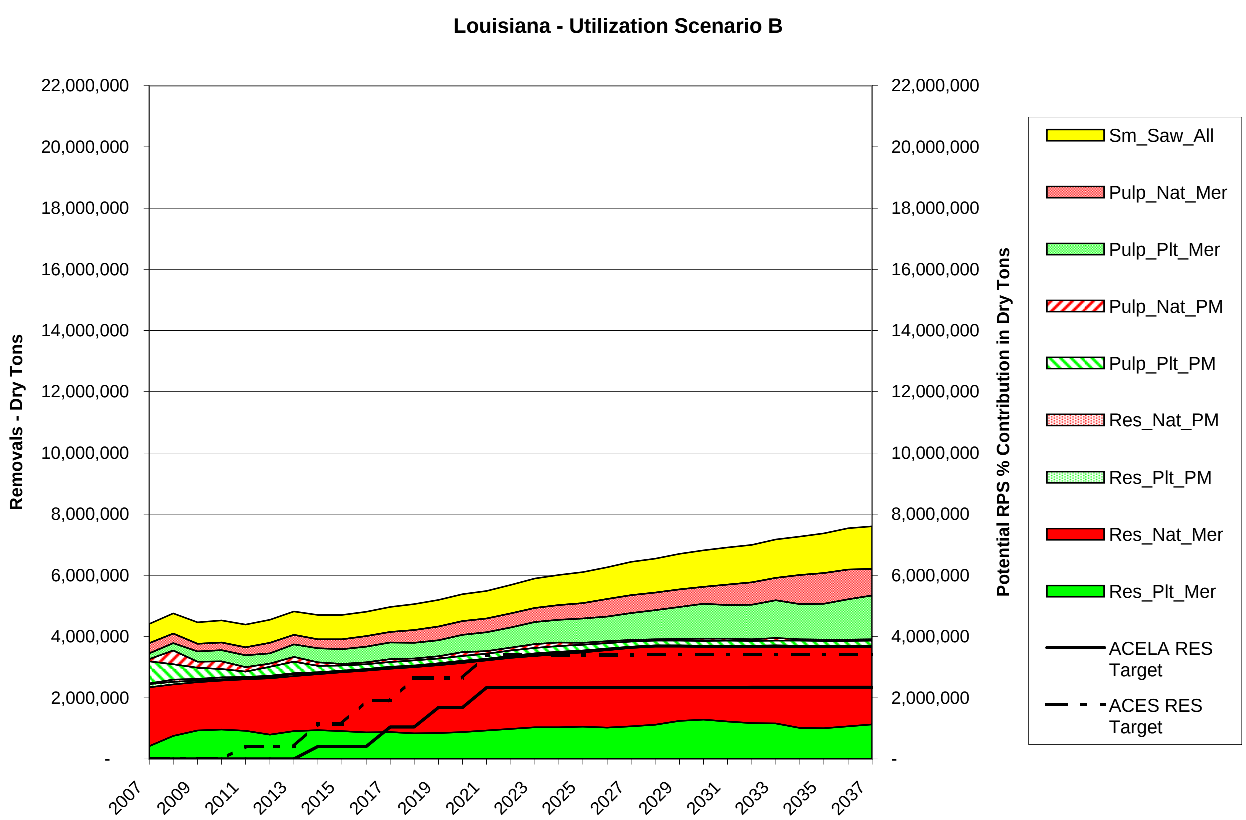


Kentucky - Utilization Scenario B



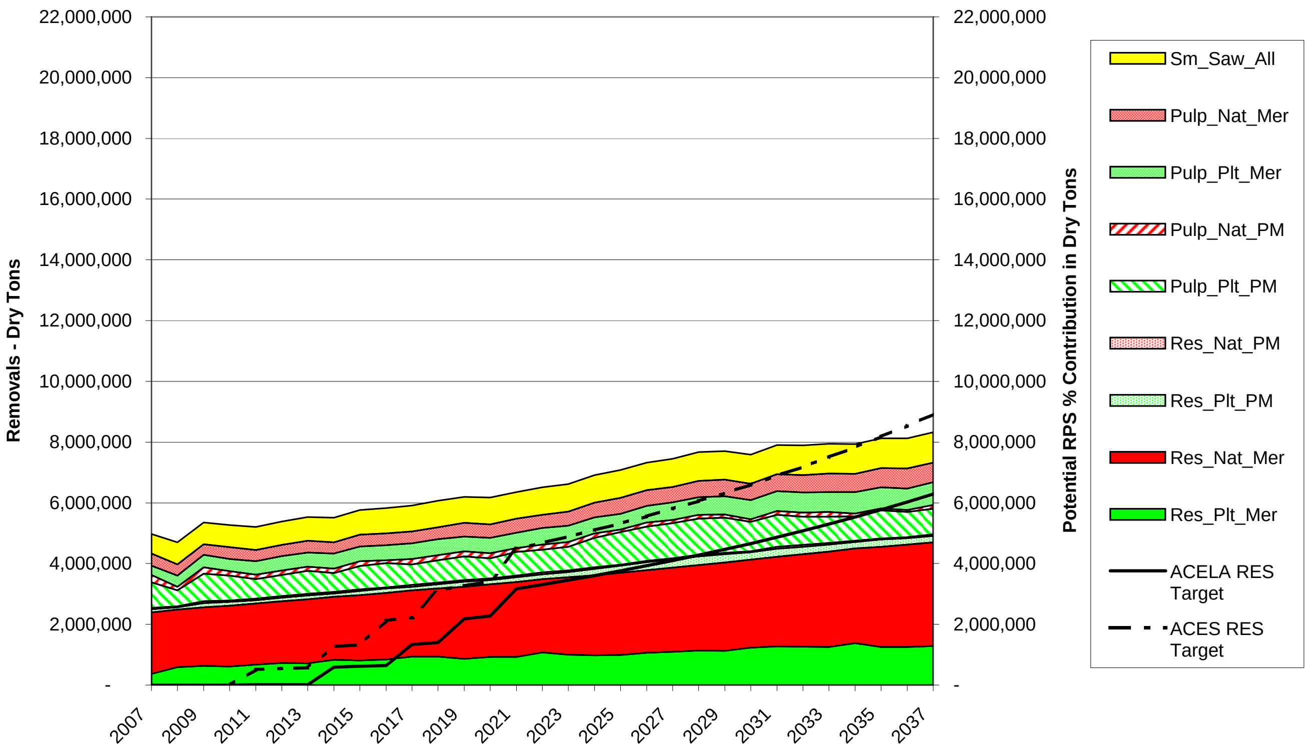
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



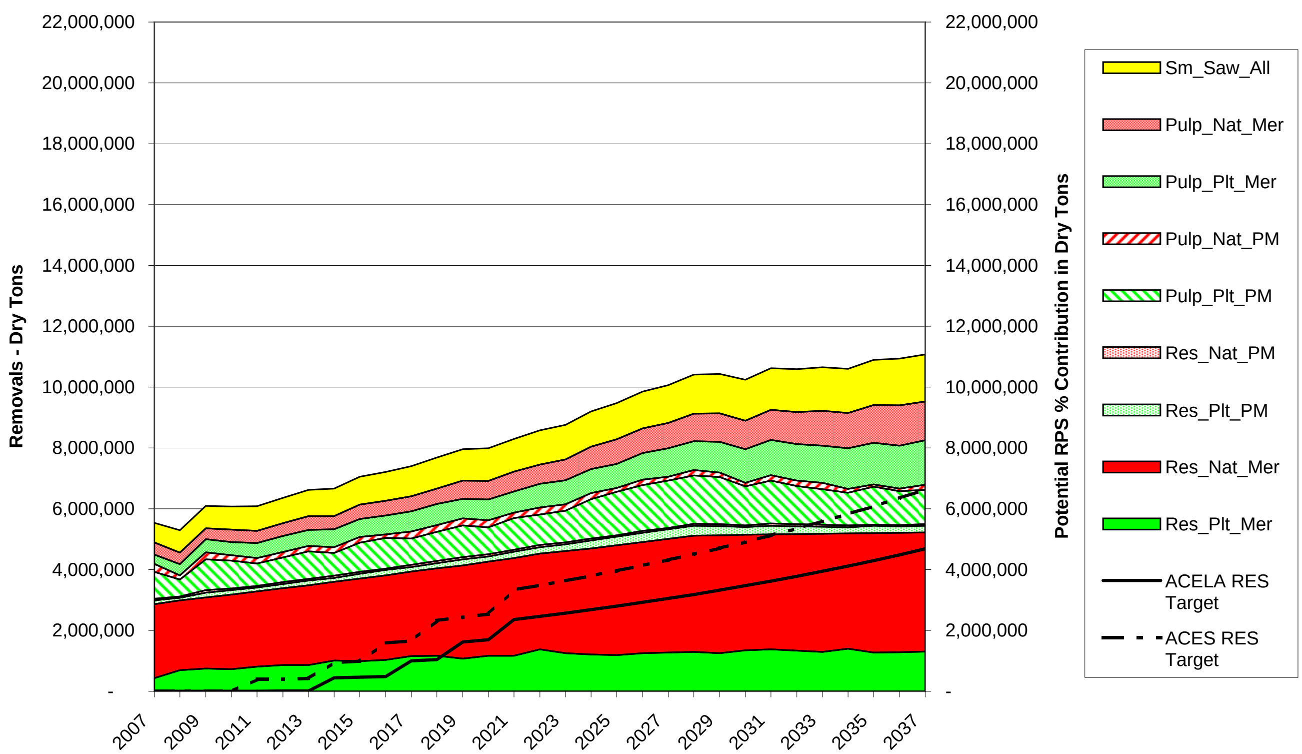


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

Mississippi - Utilization Scenario A

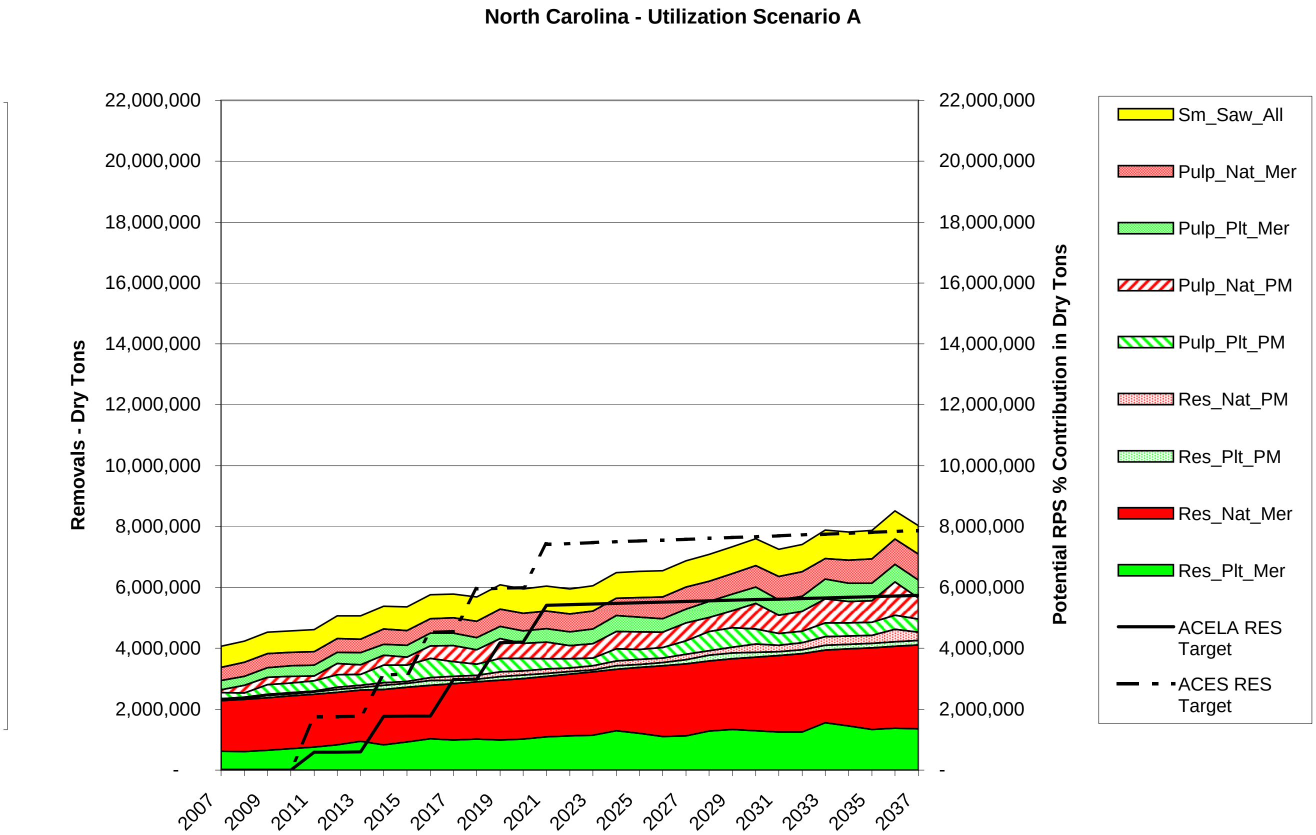


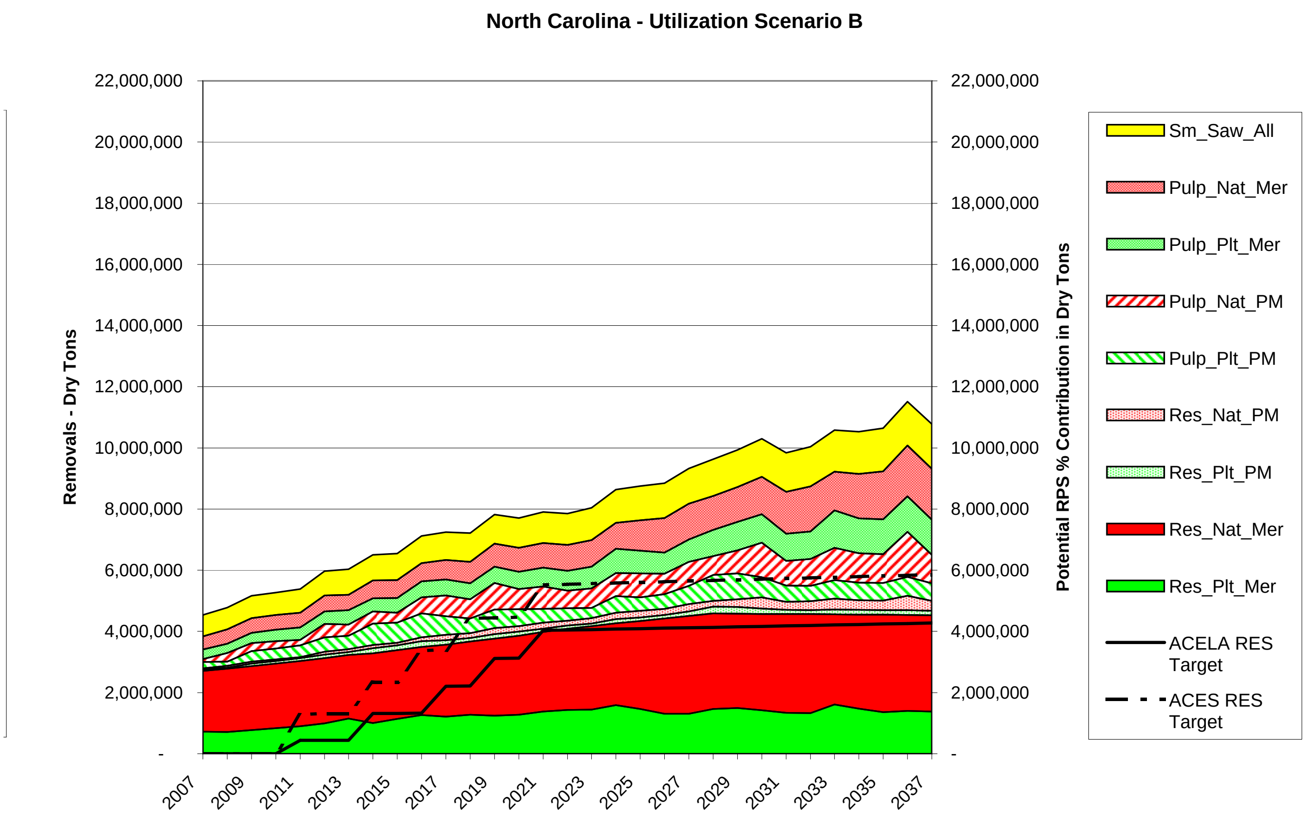
Mississippi- Utilization Scenario B



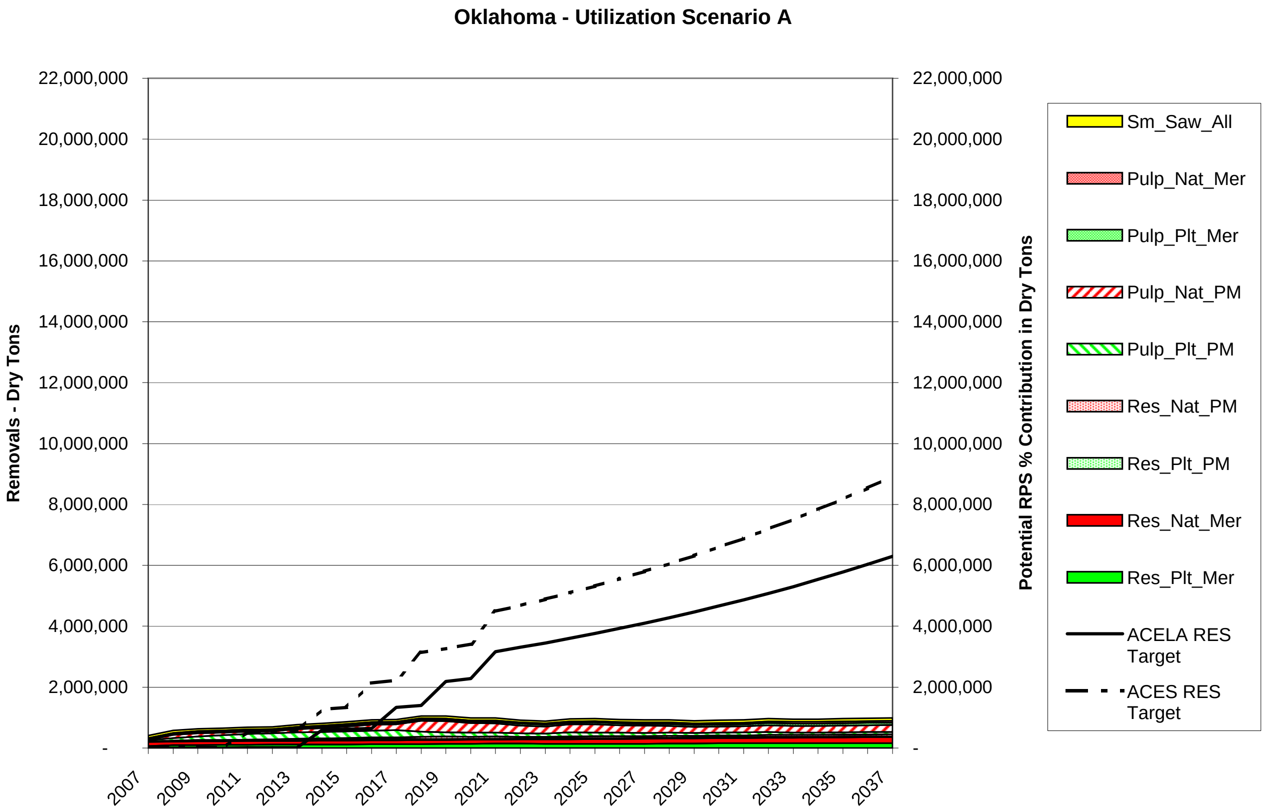
APPENDIX G

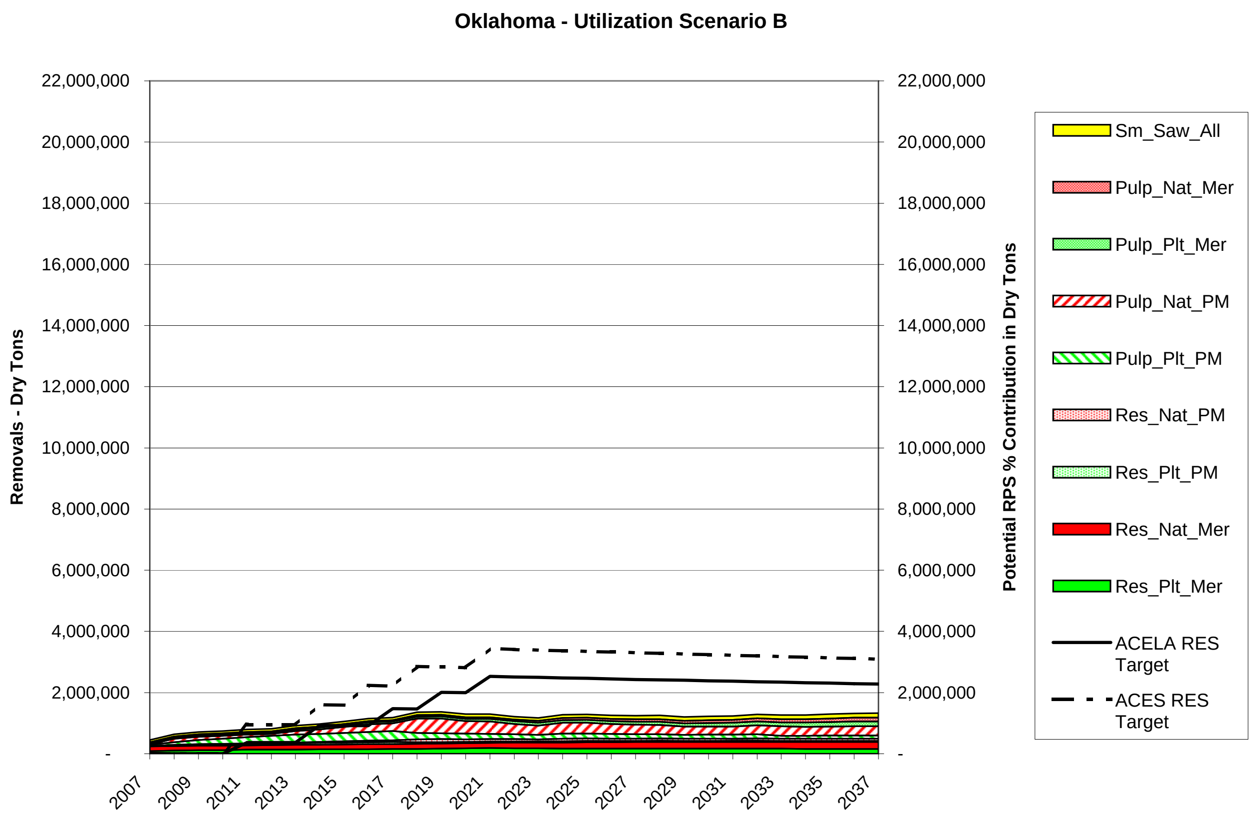
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)





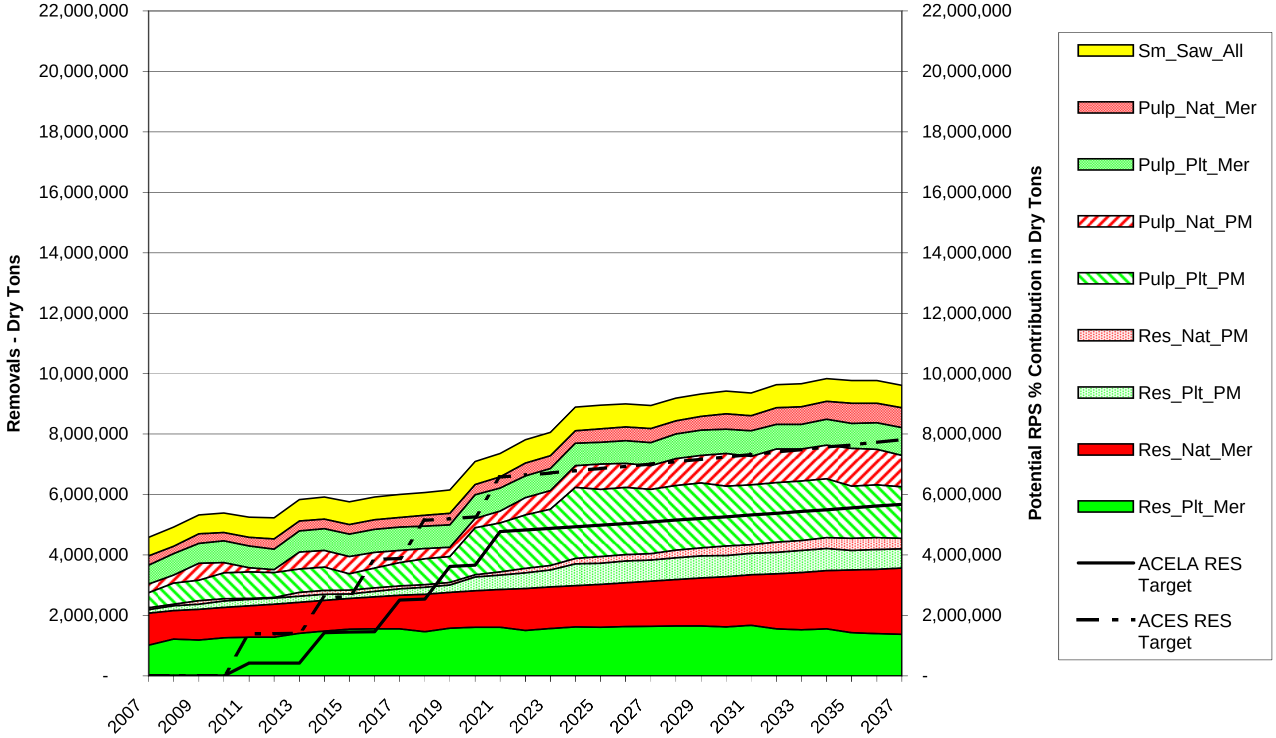
APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



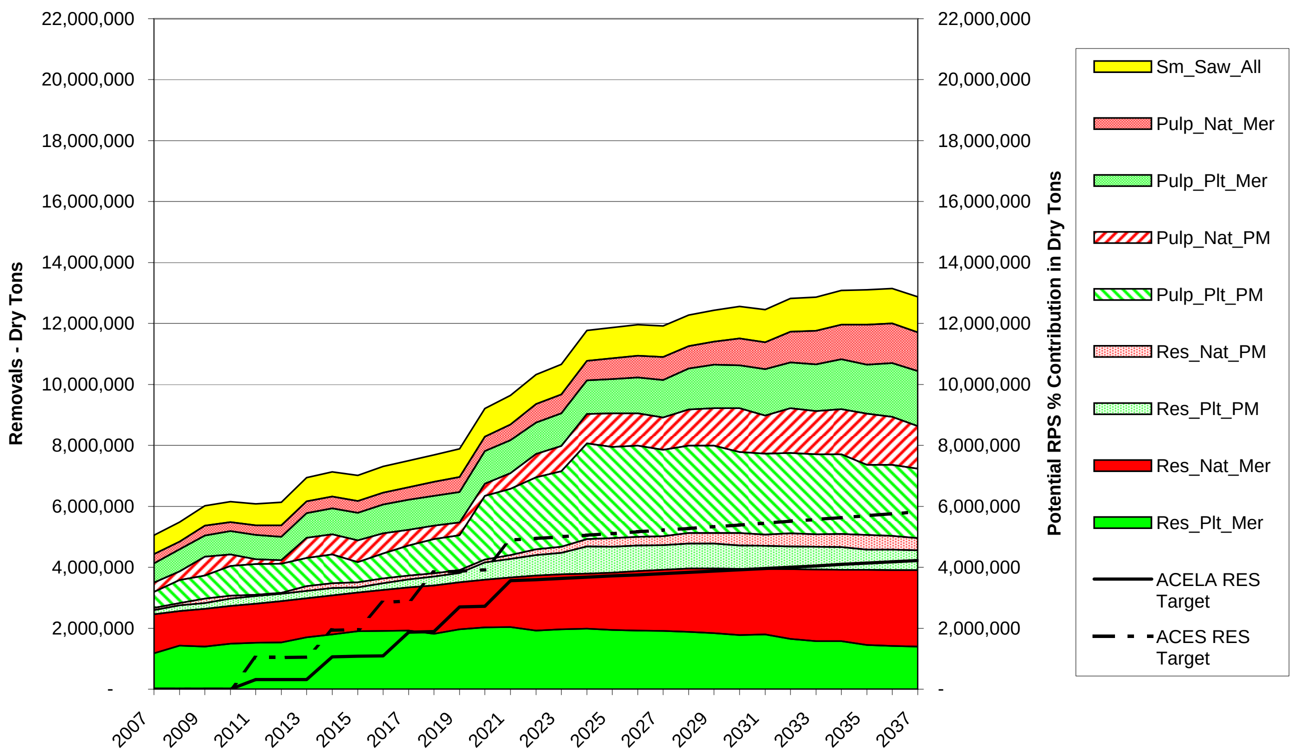


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

South Carolina - Utilization Scenario A

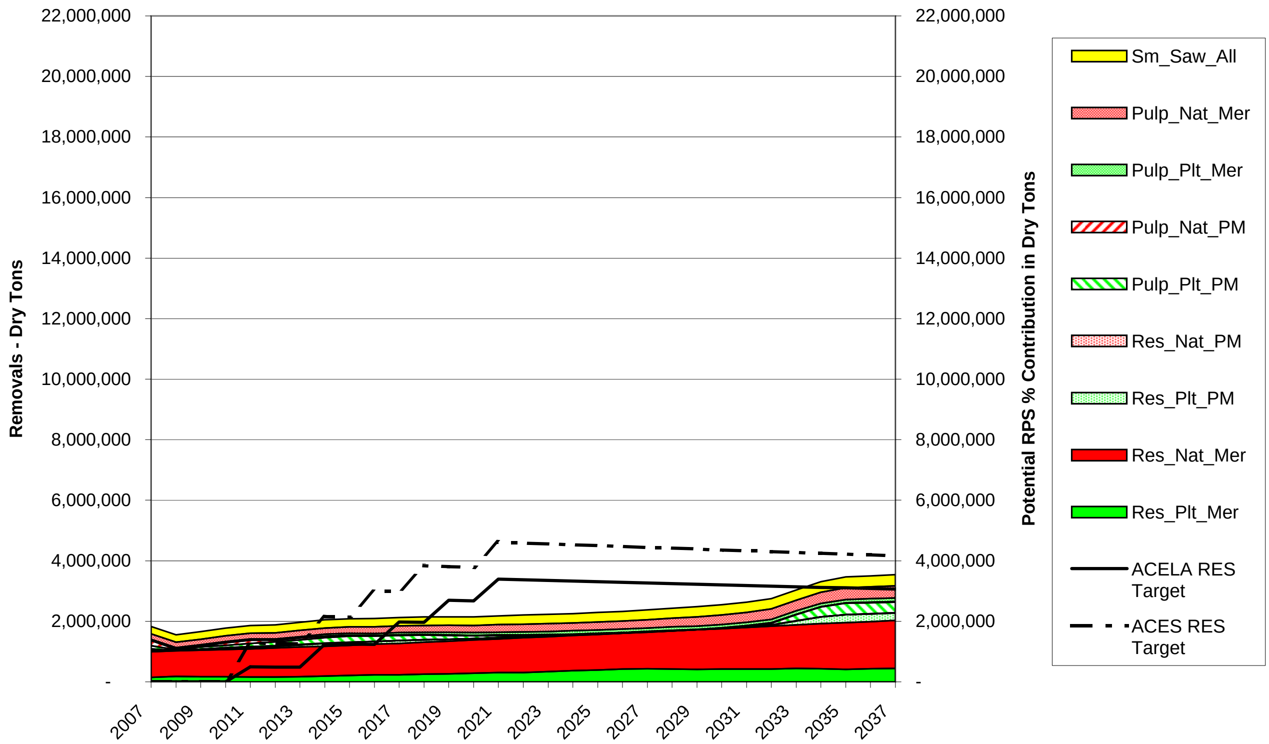


South Carolina - Utilization Scenario B

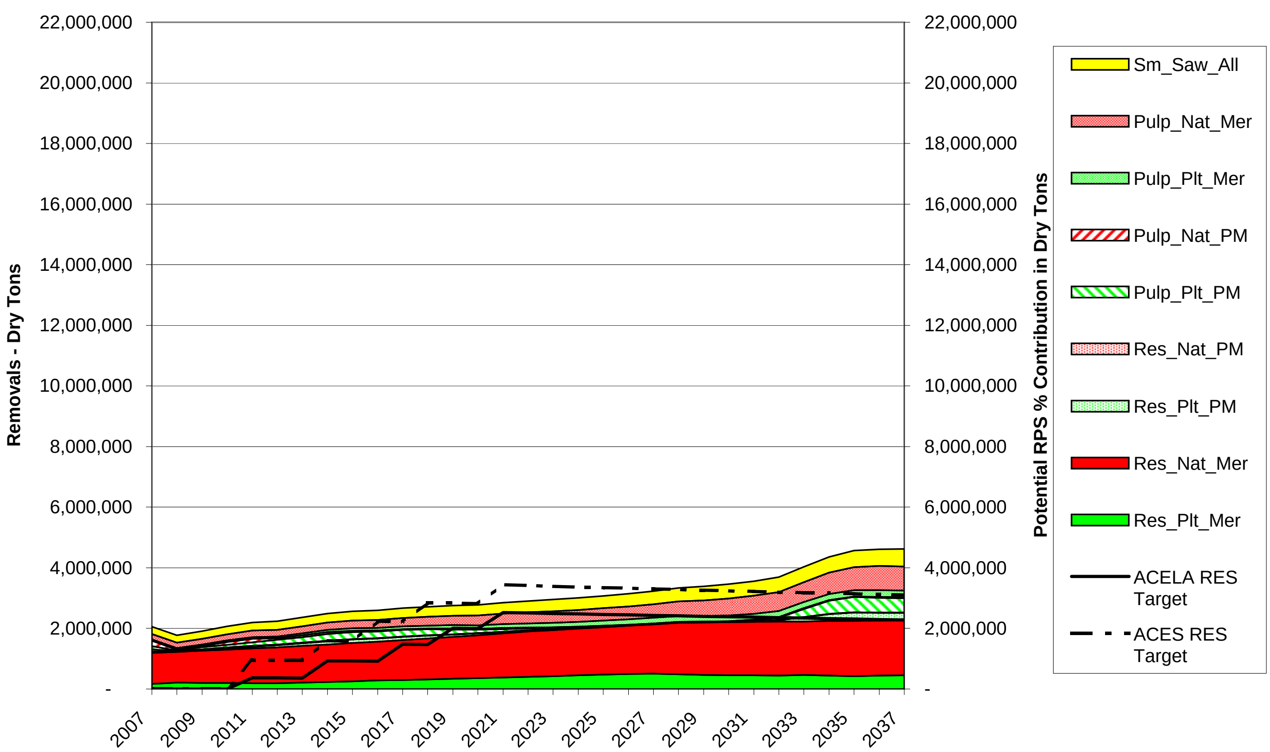


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

Tennessee - Utilization Scenario A



Tennessee - Utilization Scenario B



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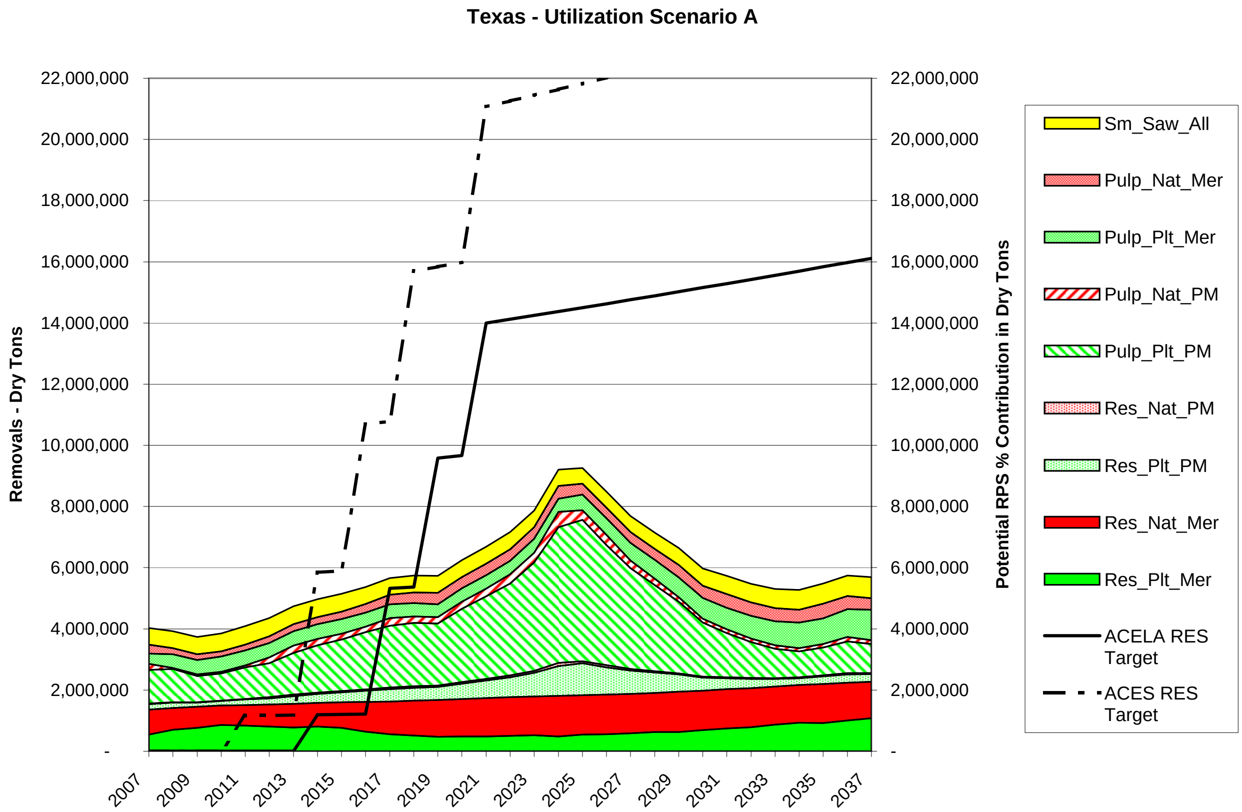
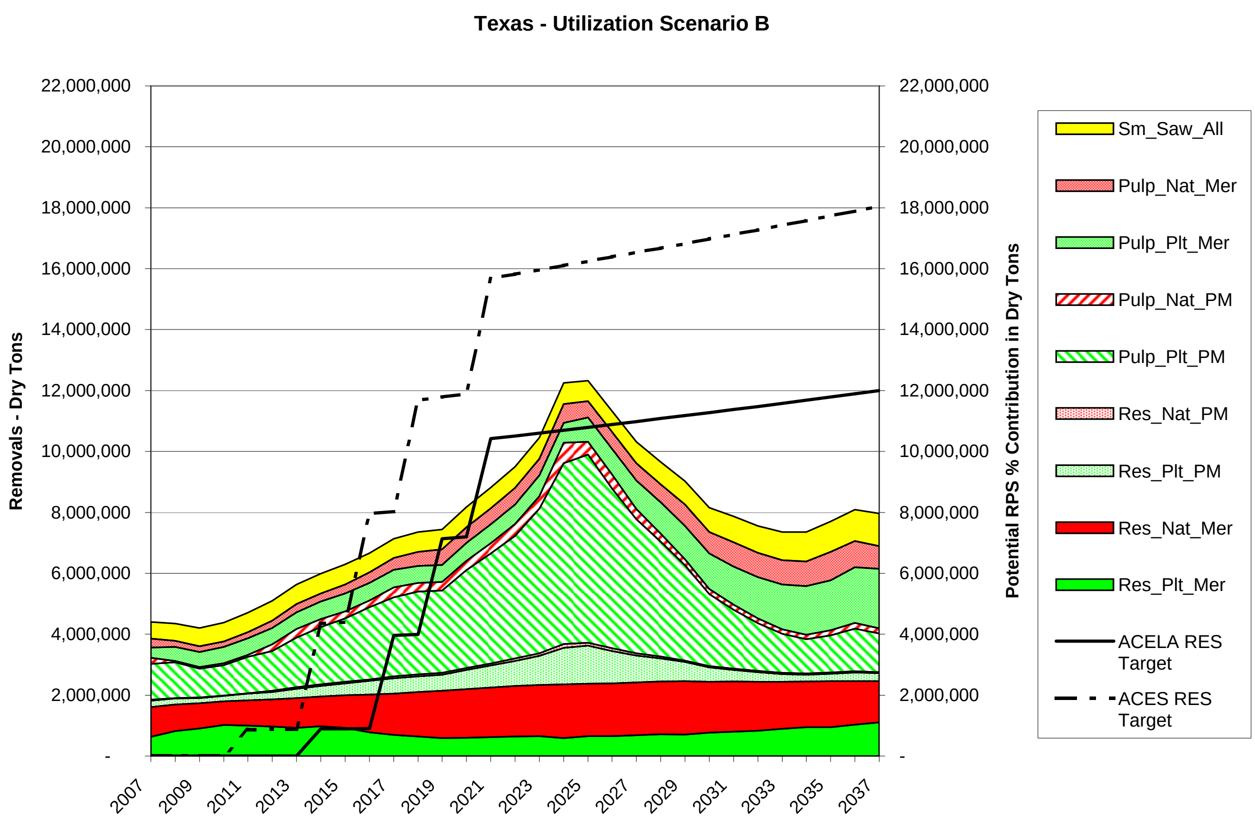
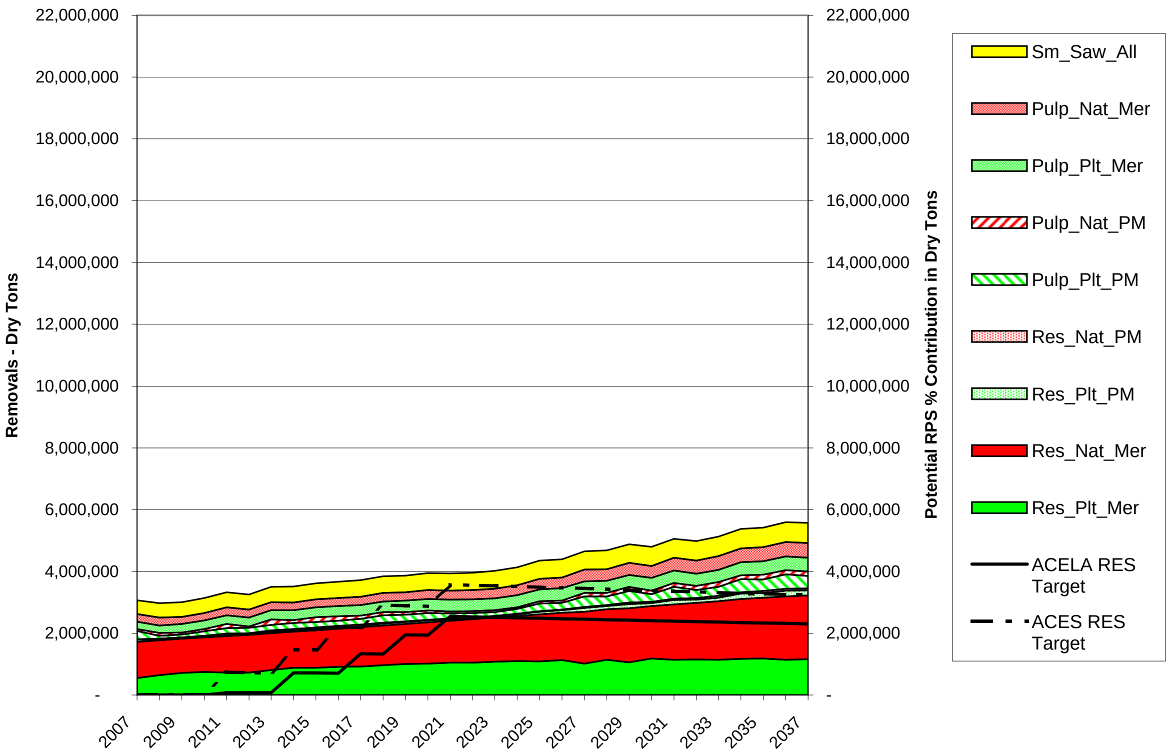
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)



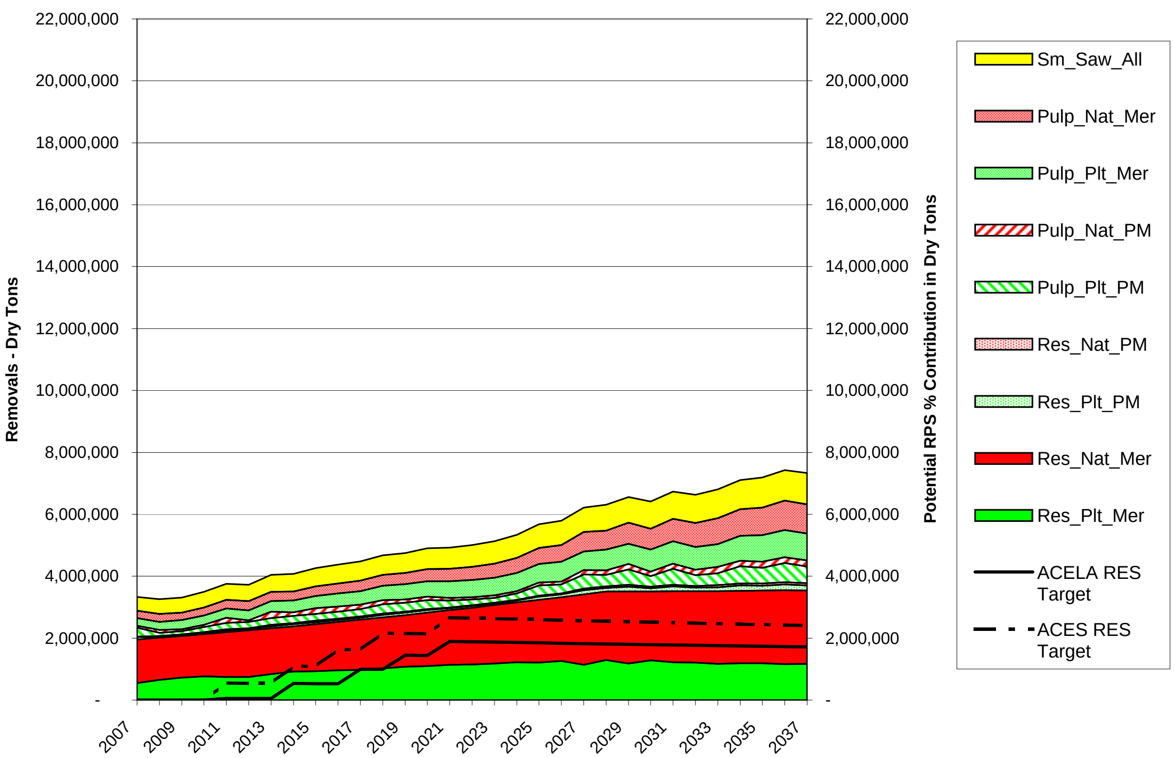


APPENDIX G
Comparison of Woody Biomass Supply (SRTS Annual Removals) to Demand (RPS Standards)

Virginia - Utilization Scenario A



Virginia - Utilization Scenario B



Glossary

Actively Managed Plantations: Artificially or manually regenerated plantations

Ag & Fallow: Land actively managed for agriculture or left fallow

Biomass Operation: Harvest operation dedicated to removal of wood material for biomass fuel source, whole tree chipping, etc.

Board Foot: The amount of wood contained in an unfinished board 1-inch thick, 12 inches long, and 12 inches wide. Abbreviated "BF." Common units as related to sawlog-volume measurement include - 1,000 BF or MBF and 1,000,000 BF or MMBF.

Bone Dry Ton: Traditional unit of measure used by industries (pulp/paper, biomass power) that utilize biomass as a primary raw material. One bone dry ton (BDT) is 2,000 pounds of biomass (usually in chip form) at zero-percent moisture. Typically biomass collected and processed in the forest is delivered "green" to the end use facility at 50-percent moisture. One BDT (assuming 50-percent moisture content) is two green tons (4,000 pounds at 50-percent moisture content).

Btu (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Byproducts: Primary wood products, e.g., pulp chips, animal bedding, and fuelwood, recycled from mill residues. Composite panels. Roundwood products manufactured into chips, wafers, strands, flakes, shavings, or sawdust and then reconstituted into a variety of panel and engineered lumber products.

Chip: A small piece of wood typically used in the manufacture of pulp/paper, composite panels, fuel for power/heat generation, and landscape cover/soil amendment.

Consumption (Fuel): The amount of fuel used for gross generation, providing standby service, start-up and/or flame stabilization

Cull log: Logs that do not meet certain minimum specifications for usability or grade. A cull log typically has very little value in the production of lumber products.

Energy Efficiency: Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatthours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Energy Source: The primary source that provides the power that is converted to electricity through chemical, mechanical, or other means. Energy sources include coal, petroleum and petroleum products, gas, water, uranium, wind, sunlight, geothermal, and other sources.

FIA: Forest Inventory and Analysis Database - USFS

Fuelwood production: The volume of roundwood harvested to produce some form of energy, e.g., heat and steam, in residential, industrial or institutional settings.

Generation (Electricity): The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Gross Generation: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

Growing-stock removals: The growing-stock volume removed from poletimber and sawtimber trees in the timberland inventory. (Note: Includes volume removed for roundwood products, logging residues, and other removals.)

Growing-stock trees: Living trees of commercial species classified as sawtimber, poletimber, saplings, and seedlings. Growing-stock trees must contain at least one 12-foot or two 8-foot logs in the saw-log portion, currently or potentially (if too small to qualify). The log(s) must meet dimension and merchantability standards and have, currently or potentially, one-third of the gross board-foot volume in sound wood.

Growing-stock volume: The cubic-foot volume of sound wood in growing-stock trees at least 5.0 inches d.b.h. from a 1-foot stump to a minimum 4.0-inch top d.o.b. of the central stem.

Industrial fuelwood: A roundwood product, with or without bark, used to generate energy at a manufacturing facility such as a wood-using mill.

Kilowatt (kW): One thousand watts.

Logging Residue: The unused merchantable portion of growing stock trees cut or destroyed during logging operations

Megawatt (MW): One million watts.

Moisture content: The amount of moisture contained in biomass material. Typically expressed as a percentage of total weight.

Natural Heritage: Network of Individual State and Federal Natural/Biological Databases

Naturally Regenerated Stands: Stands where trees are not artificially planted or seeded

Net Generation: Gross generation less the electric energy consumed at the generating station for station use.

Noncommercial species: Tree species of typically small size, poor form, or inferior quality that normally do not develop into trees suitable for industrial wood products.

Nonforest land: Land that has never supported forests and land formerly forested where timber production is precluded by development for other uses.

Nongrowing-stock sources: The net volume removed from the nongrowing-stock portions of poletimber and sawtimber trees (stumps, tops, limbs, cull sections of central stem) and from any portion of a rough, rotten, sapling, dead, or nonforest tree.

Ownership: The property owned by one ownership unit, including all parcels of land in the United States. National forest land. Federal land that has been legally designated as national forests or purchase units, and other land under the administration of the Forest Service, including experimental areas and Bankhead-Jones Title III land.

Plant residues: Wood material generated in the production of timber products at primary manufacturing plants. Coarse residues. Material, such as slabs, edgings, trim, veneer cores and ends, which is suitable for chipping. Fine residues. Material, such as sawdust, shavings, and veneer residue, which is not suitable for chipping.

Pulpwood Regeneration Cut: Harvest operation designed to removal all trees for stand regeneration purposes

Pulpwood Thinning: Harvest operation designed to improve stocking conditions and generate income from merchantable trees

Pulpwood: A roundwood product that will be reduced to individual wood fibers by chemical or mechanical means. The fibers are used to make a broad generic group of pulp products that includes paper products, as well as fiberboard, insulating board, and paperboard.

Renewable Resources: Naturally, but flow-limited resources that can be replenished. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock-limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future, they could also include the use of ocean thermal, wave, and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on-site electricity generation, distributed electricity generation, non-grid-connected generation, and demand-reduction (energy efficiency) technologies.

Rotten trees: Live trees of commercial species not containing at least one 12-foot saw log, or two noncontiguous saw logs, each 8 feet or longer, now or prospectively, primarily because of rot or missing sections, and with less than one-third of the gross board-foot tree volume in sound material.

Rough trees: Live trees of commercial species not containing at least one 12-foot saw log, or two noncontiguous saw logs, each 8 feet or longer, now or prospectively, primarily because of roughness, poor form, splits, and cracks, and with less than one-third of the gross board-foot tree volume in sound material; and live trees of noncommercial species.

Salvable dead trees: Standing or downed dead trees that were formerly growing stock and considered merchantable. Trees must be at least 5.0 inches d.b.h. to qualify.

Salvage from Fire, Insect, Weather: Harvest operation designed to recover damaged trees

Saw log: A log that meets minimum regional standards of diameter, length, and defect, intended for sawing into lumber products.

Short Ton: A unit of weight equal to 2,000 pounds

Slash & Brush: Saplings, non-commercial understory trees and downed limbs.

Standard Industrial Classification (SIC): A set of codes developed by the Office of Management and Budget, which categorizes business into groups with similar economic activities.

Timber removals: The total volume of trees removed from the timberland inventory by harvesting, cultural operations such as stand improvement, land clearing, or changes in **land use.** **(Note:** Includes roundwood products, logging residues, and other removals.)

TPO: Timber Product Output Database - USFS

Unused plant residues: Residues (coarse or fine) that are not used for any product, including fuel.

Volume (gross): Measurement of log content in log-scale board foot (see board foot definition) without deduction for defect.

Volume (net): Measurement of the actual amount of merchantable wood in log-scale board foot, after deductions for defect.

Watthour (Wh): An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

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