1. Colnes, A., et al., *Biomass Supply and Carbon Accounting for Southeastern Forests,* The Biomass Energy Resource Center, Forest Guild, and Spatial Informatics Group, February 2012

Synopsis: This report includes a literature review aimed at evaluating total supply of and demand for wood biomass for energy harvested from the US South. Authors also modeled assessments of wood bioenergy's effect on atmospheric carbon levels in comparison to fossil fuels.

Conclusions/Findings: The authors conclude that carbon debt periods for woody feedstocks used for energy range from 35-50 years, depending on the assumed energy pathway.

Deficiencies:

- Market Effects:
  - Does not include market effects or supply/demand market responses.
- Time Scale:
  - The focus on near-term carbon debt does not give appropriate weight to the displacement of fossil fuels, which contribute permanent GHG additions to the atmosphere, and the relative effect of near-term vs. long-term emissions on global temperature rise.
- Assumptions:
  - Incorrectly assumes wood not used for bioenergy would remain in the forest untouched.
  - Does not acknowledge a likely counterfactual fate that demand for other forest products would enter a basin in order to take advantage of attractive fiber supply and prices.
- Technology Efficiency:
  - Pathways modeled in this analysis do not include wood pellet fuels (only less efficient wood chips). Dedicated biomass power end use efficiencies range from 38-40%.

Summary: This study incorrectly focuses on near-term carbon debt scenarios, rather than long-term carbon emissions. The scientific community has agreed that long-term carbon emissions into the atmosphere are the cause of global temperature shifts and climate change, whereas the science on short-term carbon debts is inconclusive. Additionally, this study incorrectly assumes that all wood not used for bioenergy would remain in the forest untouched and does not take into account that wood fiber for bioenergy comes from sustainable working forests that are harvested for a variety of forest products and managed for higher-value industries such as sawtimber.

2. Mitchell, S., Harmon, M., and O'Connell, K., *Carbon Debt and Carbon Sequestration Parity in Forest Bioenergy Production,* GCB Bioenergy, May, 2012.

Synopsis: The authors discuss modeled concepts of forest carbon sequestration dynamics over time in order to compare the carbon debt repayment point and the carbon sequestration parity point. The carbon debt repayment point is the time required for woody biomass used for energy to become carbon beneficial in comparison to the initial level of forest carbon storage, while the carbon sequestration parity point is the time required for woody bioenergy feedstocks to become carbon beneficial in comparison to a counterfactual scenario in which the forest would have not been harvested, continuing to grow into perpetuity.

Conclusions/Findings: The authors conclude that wood bioenergy is an inefficient use of forests because, in the absence of increased harvests due to bioenergy demand, the forest would continue growing and sequestering carbon. They propose that the carbon offset parity point should be used to assess the emissions benefits of wood bioenergy.

Deficiencies:

- Market Effects:
  - Models a managed forest in which increased harvesting is incorrectly assumed to lead to a decrease in carbon storage. Forests in the US South are not managed on set rotations, and increases in demand have a land use change response which increases planting, forest inventories, and landscape carbon storage.
- Assumptions:
  - Compares the bioenergy scenario to a unlikely counterfactual in which forests continue to grow in perpetuity, incorrectly assuming that forests are managed strictly for the production of bioenergy feedstocks.
  - Does not acknowledge that forests become less efficient at sequestering carbon as trees reach a certain threshold and continue to age.

Summary: The study incorrectly assumes that forests are harvested and managed for bioenergy, when the reality is that wood fiber for bioenergy comes from sustainable working forests that are harvested for a variety of forest products and managed for higher-value industries such as sawtimber. The study also ignores the market response from increased demand – an increase in planting to supply this demand, which leads to increased forest inventory and higher carbon stocks.

3. Pingoud, K., T. Ekholm and I. Savolainen (2012). ***Global warming potential factors and warming payback time as climate indicators of forest biomass use.*** **Mitigation and Adaptation Strategies for Global Change 17(4): 369-386.**

Synopsis: The authors present a life cycle assessment (LCA) methodology for estimating the global warming impact of wood bioenergy in comparison to fossil fuel energy sources and the use of biomass in harvested wood products, using the forests of Southern Finland as an example.

Conclusions/Findings: The authors found that the global warming payback time increases with the diameter of the wood used for bioenergy, and that wood use in construction materials is preferable to use in bioenergy pathways.

Deficiencies:

- Market Effects:
    - Does not include market effects or supply/demand market responses.
    - Authors model forest harvesting in Finland's boreal forest, which are ecologically very different from forests in the US South.
- Assumptions:
    - Compares bioenergy use scenarios to alternate fates in which the same feedstock is used in the manufacturing of solid wood products, which is unlikely to occur.

Summary: This study assesses boreal forests from Finland, which have differing species, growth rates, and biodiversity than working forests in the US South. Furthermore, this study does not consider that different forest products are of different value. High-value wood fiber is sold into markets like sawtimber and is much too expensive for a lower-value industry like bioenergy.

4. Schulze, E. D., C. Korner, B. E. Law, H. Haber and S. Luyssaert. 2012. *Large-scale bioenergy from additional harvest of forest biomass is neither sustainable nor greenhouse gas neutral.* GCB Bioenergy: 4(6): 611-616

Synopsis: The authors use a static forest model to assess the effect of using forest biomass to produce 20% of the world's energy supply.

Conclusions/Findings: The authors conclude that increasing the use of wood feedstocks to 20% of global energy supply would have a net negative effect because it would result in younger forests, reduced biomass pools, depleted soil nutrients, and the loss of vital ecosystem functions.

Deficiencies:

- Market Effects:
  - Does not include market effects or supply/demand market responses, assuming a permanent reduction in carbon stock as a result of increased bioenergy demand.
- Spatial Scale:
  - The carbon assessment is made at the stand-level, rather than at the landscape level. Working forests in the US South are in a constant rotation of harvest and various stages of regrowth, making a landscape level assessment more accurate.
- Time Scale:
  - Argues that the upfront emissions due to reduction in forest carbon stocks from to increased harvest levels mean that atmospheric carbon is increased for decades. Market effects and spatial scale errors aside, this statement does not give appropriate weight to the displacement of fossil fuels, which contribute permanent GHG additions to the atmosphere, and the relative effect of near-term versus long-term emissions on global temperature rise.
- Assumptions:
  - Assumes forests would be left to grow in perpetuity in the absence of bioenergy demand, incorrectly assuming that forests are managed strictly for the production of bioenergy feedstocks.

Summary: This study incorrectly focuses on near-term carbon debt scenarios, rather than long-term carbon emissions. The scientific community has agreed that long-term carbon emissions into the atmosphere are the cause of global temperature shifts and climate change, whereas the science on short-term carbon debts is inconclusive. Additionally, this study incorrectly assumes that all wood not used for bioenergy would remain in the forest untouched and does not take into account that wood fiber for bioenergy comes from sustainable working forests that are harvested for a variety of forest products and managed for higher-value industries such as sawtimber.

5. Hagan, J., *Biomass Energy Recalibrated,* The Manomet Center for Conservation Sciences, January 2012.

6. Walker, T., et al., *Biomass Sustainability and Carbon Policy Study,* The Manomet Center for Conservation Sciences, June 2010.

Synopsis: Manomet and its partners released the results of a study conducted for the Massachusetts Department of Energy Resources to better understand the implications of using wood for energy in Massachusetts.

Conclusions/Findings: These studies analyze Massachusetts' forests to determine biomass impacts on forest growth and carbon and find negative impacts on carbon stocks and forest inventory resulting from the use of biomass for energy.

Deficiencies:

- Market Effects:
  - Ignores that Massachusetts' forests have differing characteristics and markets than southern forests.
  - Fails to recognize that the value of sawtimber is too high for forest landowners to sell sawtimber into a low-paying market, like bioenergy. For example: For forest owners to switch markets and sell sawtimber into bioenergy markets, as Hagan suggests, would take a catastrophic failure of housing markets, worse than the 2008 collapse, and a simultaneous extreme increase in fossil fuel and natural gas prices to occur.
  - Ignores the impact of healthy markets and demands on incentivizing landowners to replant following a harvest.
- Spatial Scale:
  - The carbon assessment is made at the stand-level, rather than at the landscape level. Working forests in the US South are in a constant rotation of harvest and various stages of regrowth, making a landscape level assessment more accurate.
- Time Scale:
  - Ignores the full carbon life cycle, including carbon already present in the forest.
  - Fails to acknowledge that the use of bioenergy for electricity, even in the absence of heat capture, reduces the emissions of burning fossil fuels for electricity.
- Assumptions:
  - Incorrectly claims forests will grow in perpetuity in the absence of bioenergy demand.
  - Incorrectly infers forests are managed strictly for the production of bioenergy feedstocks.

Summary: This study ignores the basic market forces at play in the forest products industry, namely that forests are managed and harvested for the high-paying sawtimber industry. This, together with additional misconceptions regarding the biogenic carbon cycle lead to incorrect assumptions about the impact of bioenergy on forest resources and carbon stocks.

Additional Notes: The Pinchot Institute for Conservation, a non-partisan conservation research institution and a research participant in this study, held a subsequent media advisory following their report in which their President Al Sample made the following remarks in response to erroneous conclusions drawn by the media upon release of this study:

- The rapidly spreading assertion that biomass is dirtier than coal "couldn't be further from the truth".
- "It was a gross simplification that resulted in the misinterpretation of the study's overall conclusions."

7. Stephenson, A. L., and MacKay , D., *Life Cycle Impacts of Biomass Electricity in 2020: Scenarios for Assessing the Greenhouse Gas Impacts and Energy Input Requirements of Using North American Woody Biomass for Electricity Generation in the UK,* UK Department of Energy and Climate Change, July 2014.

Synopsis: In 2014, researchers at the former UK Department of Energy and Climate Change released a report which analyzes multiple scenarios within the forest industry in the southeastern US and the impact of these scenarios on assessing the carbon intensity of using woody biomass for electricity.

Conclusions/Findings: Through a series of assumptions and counterfactual modeling, this report draws a variety of conclusions based upon differing scenarios, some showing low carbon and some showing high carbon from using woody biomass for energy production.

Deficiencies:

- Market Effects:
  - Does not include market effects or supply/demand market responses.
  - This study does not analyze the likelihood of any suggested scenarios actually occurring in the southeastern US forest market.
- Assumptions:
  - This report employs the use of scenarios and counterfactuals that are not realistic to forest markets in the US South including:
    - Incorrect assumption that sawtimber-quality wood is used for bioenergy with forests managed and harvested solely for bioenergy production.
    - Incorrect calculation of average harvesting rates in the US. For example, the report quotes 70+ years for hardwood harvest rotations, when US Forest Service data shows an average of 50-55 years.
    - Incorrect assumption that low-value bioenergy markets would strongly influence landowner harvesting and management decisions.

Summary: This study ignores the basic market forces at play in the forest products industry, namely that forests are managed and harvested for the high-paying sawtimber industry and not for bioenergy. Additionally, the scenarios introduced in this study are extremely unrealistic and unlikely to occur at all in the forest market in the US South.

Additional Notes: In 2015, the former UK Department of Energy and Climate Change commissioned a second study to analyze the likelihood of the scenarios in this 2014 study occurring due to increased bioenergy demand. This follow up study was released in 2017 and concluded that only 5 of the 38 scenarios were even moderately likely to occur, and none of them would occur "as a result of pellet demand alone, because financial return is not adequate and sustainability requirements would not allow this change".

8. Repo, A., et al., *Sustainability of Forest Bioenergy in Europe: Land-use-related Carbon Dioxide Emissions of Forest Harvest Residues,* GCB Bioenergy, March 2014.

Synopsis: The paper looks at how changes in carbon stored in soil and litter, due to increased biomass use, affect the intention to reduce greenhouse gas emissions. The geographic scope is Europe.

Conclusions/Findings: The authors quantified forest residuals and litter available in different European countries that could be used for biomass power generation, compatible with sustainable forestry. They compared emissions from power generation (of heat or electricity), with CO_2 emissions and soil sequestration of carbon that would have occurred if those residuals had been left in the forest. The comparisons are made at discrete points in the future from 2020 to 2095. They find that bioenergy production from these feedstocks is worse than fossil fuel in the short term and would need to continue for 60 to 80 years to achieve a 60% CO_2 emission reduction compared to fossil fuels.

Deficiencies:

- Market Effects:
  - Does not include market effects or supply/demand market responses.
  - Does not consider the economic capacity to improve forest management due to the additional market being available.
  - Does not consider to what extent forests stay as forests because of an additional market being available for forest owners.
- Assumptions:
  - Analysis does not include possible effects of changes in forest management or species composition.
  - Does not consider the difference in decay rates and soil structures between the US South and Northern Europe. The analysis is focused on European forests, so is not useful for understanding the dynamics of forests in US South, particularly concerning decay rates of harvest residue, which are faster in warmer climates.
  - Compares emissions of CO_2 from generating electricity/heat with forest residuals to the counterfactual of CO_2 emissions from fossil fuel. The correct counterfactual would be fossil fuel emissions PLUS emissions from decaying forest residuals that could have been used for power generation.
  - Levels of available biomass in this study were derived without consideration of local market conditions.
- Technology Efficiency:
  - Pathways modeled in this analysis assumed conversion efficiency to be just 25%, whereas in modern dedicated power stations using wood pellets see a conversion efficiency of 38-40%. The study therefore significantly overstates CO_2 emissions from the use of biomass in electricity generation.

Summary: This study is not relevant to forestry in the US, as it does not address the market forces in the US forest products market or the biological aspects of forests and soils in the US South.

9. Ter-Mikaelian, M., et al., *Carbon Debt Repayment or Carbon Sequestration Parity? Lessons from a Forest Bioenergy Case Study in Ontario, Canada,* GCB Bioenergy, May 2014.

Synopsis: The paper assesses changes in CO_2 emissions at Atikokan Generating Station in Ontario, Canada, making comparisons if coal is substituted by pellets made from forest residues, or by pellets made from stemwood from additional harvesting.

Conclusions/Findings: The study discusses two metrics, time to carbon "sequestration parity" and time to "carbon debt repayment". It found that for the residue scenario, sequestration parity was achieved in one year. In the stemwood scenario, times to carbon sequestration parity and carbon debt repayment were 91 and 112 years respectively; this scenario requires the regenerating forest to sequester carbon to offset extra emissions from combustion of biomass. Modelling found increasing growth rates for stemwood substantially reduce time to carbon sequestration parity.

Deficiencies:

- Market Effects:
  - Does not include market effects or supply/demand market responses.
  - Does not consider whether additional markets can help keep forests as forests, rather than converting to another land-use. This is a reality in the US South where private ownership is prevalent.
  - Does not consider the capacity for investment in better forest management provided by the opportunity to sell otherwise un-merchantable material.
- Assumptions:
  - Considers forests in northern Ontario, with maximum annual increments of just $1.5m^3$ to $4.5m^3$ per ha per year. In the US South, growth rates can be 6 to 10 times faster than those in the study, resulting in different outcomes for cumulative greenhouse gas emissions and carbon sequestration calculations. The study itself acknowledges that "yield curves had the largest effect on total cumulative GHG emissions and times to carbon sequestration parity."
  - Makes unrealistic assumptions about the biomass harvesting process, theorizing a completely separate, non-existent biomass harvest that only uses the stemwood component of the harvest.
  - Incorrectly assumes all wood for bioenergy is diverted from current use in other wood markets
  - Does not consider the potential for oversupply or surplus of fiber, such as the one currently ongoing in the US South.
  - Incorrectly assumes that forest growth, successional change, and natural disturbance remain constant which is not accurate in the US South.
  - Incorrectly assumes extra felling of forest stands specifically for pellets. This is highly unlikely to occur as there will more valuable products in a stand.
  - Does not consider the positive contributes that advances in plantation forestry practices can make for soil conditions and forest productivity.
- Technology Efficiency:
  - The model assumed 1.52 or 1.736 MWh/tonne of pellets. Modern biomass generators achieve close to 2MWh/tonne of pellets.

Summary: The unrealistic assumptions, slow growth rates, and modest efficiency make this study very limited in its applicability.