IEA Bioenergy

Is energy from woody biomass positive for the climate?

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Energy from woody biomass can be very positive for the climate, particularly when applying sustainable forest management practices, and when the biomass is used efficiently (such as in combined heat and power plants and biorefineries).

Considering the crucial role of forests to the climate and many other ecosystem services, **sustainable forest management is key to maintaining healthy and productive forests, and for controlling harvest levels so as to maintain or increase carbon stocks in forests**[1]. Within this overall framework, efforts to increase global forest area through reforestation and afforestation, and management strategies aimed at maintaining or increasing carbon stocks, while also producing an annual sustained yield of timber, fibre and energy from forests are very important for climate change mitigation; these strategies contribute to **replacing carbon-intensive materials and fossil fuels, which is crucial in future decarbonisation strategies**.

Most woody biomass sourced for energy is a by-product or residue of forestry operations and forest industry. Examples from forest management include thinnings, diseased or low quality trees, tops and branches; examples from forest industry include shavings, sawdust, bark and black liquor. Generally, the primary forest sector aim is to produce high value products, such as sawnwood and wood panels, or pulp and paper. **Using by-products and residues for energy has typically been found to achieve climate change mitigation benefits in the short term**. It is not recommended to use long-rotation high quality stemwood for energy[2], or cutting entire forests to generate bioenergy. Nevertheless, lower-value roundwood from short rotation forestry, thinnings, diseased or low quality trees should not be excluded.

1. *Fossil vs biogenic CO_2 emissions*

Some people are puzzled about how bioenergy can contribute to climate change mitigation because burning biomass emits carbon dioxide (CO_2). There have even been headlines in the media claiming that “biomass is worse than coal”. In fact, it is perfectly true that a bit more CO_2 is released per unit energy from biomass than from black coal – this is purely a consequence of the chemical composition of biomass and coal. However, statements like “the use of woody biomass for energy will release higher levels of emissions than coal” overlook the fundamental difference between energy supply

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[1] *Sustainable forestry is vital for many reasons – also from a carbon balance perspective. Valuable forests need to be protected and forestry methods in production forests need to be sustainable. To determine whether a forest system is managed sustainably requires consideration of a wide range of factors, which together determine a forest’s biodiversity, productivity, regeneration capacity, vitality and potential to fulfil relevant ecological, economic and social functions. Considerations beyond climate effects of woody biomass use for energy are however outside the scope of this brief.*

[2] *In practice, high quality stemwood is not used for bioenergy on a significant scale, because the paying capacity of saw mills and other users of high quality stemwood is much higher than prices that can be paid by the bioenergy industry, even when taking current subsidy levels for bioenergy into account.*

from fossil fuels and from biomass: **burning fossil fuels releases carbon that has been locked up in the ground for millions of years, while burning biomass emits carbon that is part of the biogenic carbon cycle**. In other words, fossil fuel use increases the total amount of carbon in the biosphere-atmosphere system while bioenergy systems operates *within* this system; biomass combustion simply returns to the atmosphere the carbon that was absorbed as the plants grew (Figure 1).

The net greenhouse gas (GHG) outcome of using biomass for energy cannot be determined by comparing emissions at the point of combustion. Instead, the biogenic carbon flows and any fossil GHG emissions associated with the bioenergy system need to be compared with the GHG emissions associated with the energy system displaced, considering also biogenic carbon flows in the absence of the bioenergy system.

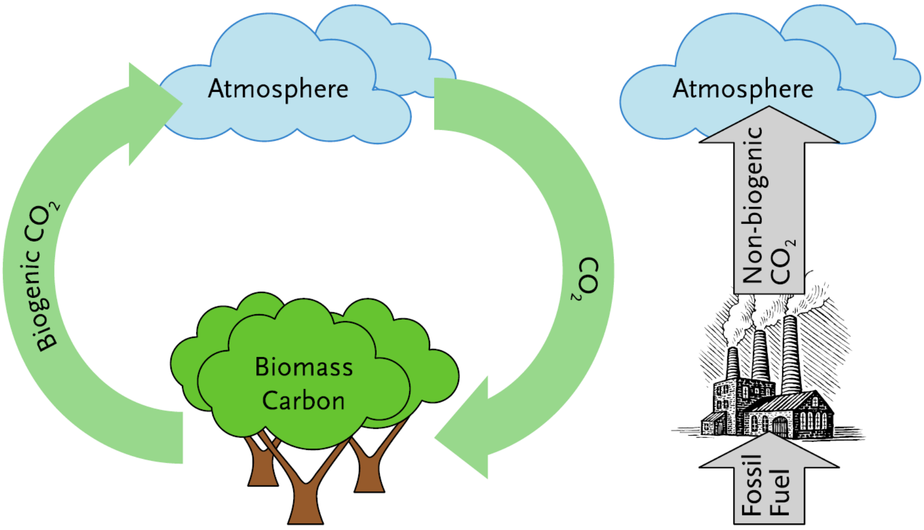

Figure 1: IPCC distinguishes between the slow domain of the carbon cycle, where turnover times exceed 10,000 years, and the fast domain (the atmosphere, ocean, vegetation and soil), vegetation and soil carbon have turnover times in the magnitude of 1– 100 and 10– 500 years, respectively. Fossil fuel transfers carbon from the slow domain to the fast domain, while bioenergy systems operate within the fast domain. (source: National Council for Air and Stream Improvement)

2. *Carbon neutrality*

Bioenergy is commonly said to be "carbon neutral", but this is an unhelpful term because it is ambiguous, and used differently in different contexts. Within the biospheric carbon cycle, bioenergy can be carbon neutral because the carbon that is released during combustion has previously been sequestered from the atmosphere and will be sequestered again as the plants regrow, i.e. if sustainably produced. However, **the full supply chain must be considered**, and all emissions associated with the production, processing, transport and use of bioenergy need to be included. Particularly harvesting, transport and processing generally involves fossil energy use. Nevertheless, analysis shows that the **fossil energy used in the supply chain is generally a small fraction of the energy content of the bioenergy product**, even for woody biomass transported over long distance, e.g. between North America and Europe.

The important issues in terms of climate impacts relate to **how the forest carbon cycle is affected by management changes to provide biomass for bioenergy in addition to other forest products**. With respect to the forest, the key issue is the net assimilation of carbon (carbon sink strength) and associated changes in carbon stock in forest soils and vegetation and/or harvested wood products, and carbon losses through natural disturbances such as fires or insect attacks.

3. Timing of greenhouse gas emissions

Another important issue which is often raised is the asynchrony between the timing of emissions and sequestration, particularly when biomass is obtained from long rotation forests, where a stand takes decades to regrow. In reality, a forest usually comprises stands of different ages, managed such that different stands are harvested each year. Thus, **considered across the whole forest estate, stand level fluctuations in carbon stock are evened out**. If the annual cut is equal to the annual growth, at estate level, the carbon stock of the whole forest will remain constant. If the annual cut is less than the annual growth, the forest will have a net sequestration of carbon, while also providing wood for products and biomass for energy. It is important to note that if a forest is converted to a new management regime where more residues are extracted or rotation length is reduced, the carbon stock of the forest estate may decrease, and this should be included as an emission of the bioenergy system. It is also possible that enhanced management (e.g. improved site preparation, use of nurse trees, advanced genetics) stimulated by the demand for bioenergy, will reduce or even negate any decline in carbon stock under the bioenergy scenario.

If the bioenergy scenario does cause a reduction in forest carbon stocks, this carbon cost can be repaid if the biomass displaces use of fossil energy sources. Climate benefits will continue to accumulate with each successive harvest. The payback time can be almost immediate when biomass is obtained from annual plants or residues that would otherwise decay rapidly, and are used efficiently (such as in combined heat and power plants or biorefineries) to displace greenhouse gas-intensive fossil resources. Bioenergy based on by-products from forest industry processes (sawdust, bark, black liquor etc.), as well as tops and branches and biomass from some silviculture operations such as fire prevention and salvage logging are typically found to achieve climate change mitigation in the short term. However, some studies have shown payback times of decades or longer in other bioenergy systems, particularly when considering slowly decaying residues and long-rotation roundwood as feedstock.

Nevertheless, the focus on short term carbon balances may be misleading. Considering the long residence time of CO_2 in the atmosphere, it is less important whether carbon in forest residues is emitted to the atmosphere soon after the forestry operations take place (such as when used for energy) or is emitted in the course of the next few decades (such as when the residues are left in the forest to decay). **What matters most is whether increasing use of forest biomass for energy leads to systematic changes in the forest carbon stocks and a reduction of fossil energy use**.

4. *Forest management and market responses*

Biomass extraction for energy is one of many interacting factors influencing the development of forest carbon stocks. Forest management to supply other product markets (Figure 2), the forest ecosystem structure (species composition), and natural conditions (climate, soil type, topography) also have an impact on development of carbon stocks. **In a sustainably managed forest, silvicultural operations and harvest activities are coordinated across the forest landscape to maintain a healthy forest and to obtain a continuous flow of wood for society, while maintaining or increasing wood volume in the forest**. Carbon losses (through harvest) in some stands are balanced by carbon gains (growth) in other stands, so that across the whole forest landscape the fluctuations in carbon stock even out. In their fifth assessment report, IPCC stated that in the long term, such sustainable forest management strategies will generate the largest sustained greenhouse gas mitigation benefit from forests (through the combination of maintaining/increasing carbon storage in the forest, and replacing carbon-intensive materials and fossil fuels).

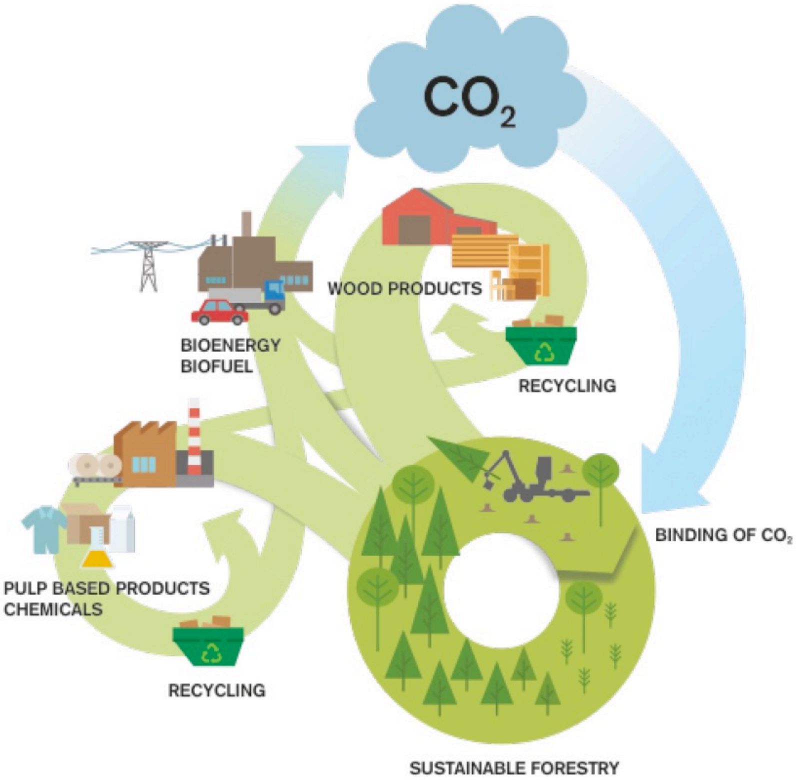

Figure 2: Forest bioenergy systems are often components in value chains or production processes that also produce material products, such as sawnwood, pulp, paper, and chemicals.

Climate impacts of bioenergy are commonly quantified by comparing with a reference "no-bioenergy" scenario. Some claim that forests would remain unharvested and continue to grow in the reference scenario; however, extraction of biomass for bioenergy is generally not the main economic driver for wood harvests. Moreover, **unharvested forests have declining carbon uptake over time** because growth rates diminish as forests get older and approach maturity, or high tree density constrains further growth. As growth rates decrease, the forest moves towards a steady-state, where carbon uptake is balanced with the carbon release from decaying trees that died from natural causes. Unmanaged forests are also at greater risk of disturbance from fires, storms and insect attacks, which can lead to high decreases in carbon stocks.

Thinning, where some smaller trees are cut to promote better growth of the remaining trees, is the main method of influencing growth and development in production forests. Thinning promotes the production of high-quality stemwood and can stimulate increased growth rate of the forest stand. Thus, **utilisation of thinned trees for bioenergy is beneficial both to the carbon balance of the forest-product system and also to future production of high-value timber** (harvested stemwood), which is typically much less greenhouse-intensive than alternatives such as concrete, steel or bricks.

Forest management is linked to economic incentives and market expectations of forest owners for different forest products. Emerging bioenergy markets, along with the outlook for other forest product markets, influence the decisions of forest managers. **A market for bioenergy can support investment in forest improvement** – to enhance health and productivity of the forest, which in turn positively influences forest carbon stocks. For example, forest owners that are positive about future forest product markets may implement measures to protect their forests against disturbances, replanting and tending the forest and introducing more productive tree species and provenances where appropriate. They may also be less inclined to convert forested areas to agriculture or other land uses in regions where legislation does not prevent conversion, and they may even be inclined to increase the forested area. Moreover, **reforestation and afforestation of degraded lands** results in carbon sequestration in biomass and soils; to the extent that bioenergy demand is a driver for such activities the carbon sequestration can be considered an additional contribution to climate mitigation provided by the bioenergy system.

Further reading:

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Further Information

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