Case Study Summary:

The Impact of Biomass Combustion on Carbon Emissions

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The use of biomass for energy has been considered by regulators to be carbon neutral, given that the CO2 emissions from combustion are equal to the CO2 absorbed during the growth of the biomass; an assumption originating from the national greenhouse gas inventories of the United Nations Framework Convention on Climate Change (UNFCCC). Supply chain GHG emissions (e.g. forest operations and transport) were not included in this debate as they are already accounted for in reporting to Ofgem and are not considered to be contentious.

Searchinger et al. (2009) challenged the carbon neutrality assumption on the basis that combustion emissions are not included in the accounting process. It was also argued that the counterfactual must be considered in any calculation of biomass emissions - the counterfactual describes the most likely alternative scenario in the absence of biomass demand (e.g. that harvesting might not take place, that the biomass would be used in other markets or that the biomass would be left on site to rot). The counterfactual debate has some validity, but it also introduces a considerable amount of uncertainty; for any given feedstock, forest type, ownership objective, or market scenario, there are multiple combinations of potential counterfactuals, even before considering the biological variables of each feedstock and forest type.

Another challenge to calculating the impact of biomass demand on forest carbon is the question of which baseline to use as the point of comparison. For an individual tree, or stand of trees, it could be at the point of planting (establishment), the point of harvesting or at another specific point in the rotation (e.g. at a point in time when the forest owner decides that the objective of management is wholly or partially for biomass production). Lamers et al. (2013) observed that from a forest owner perspective, the natural baseline is at the time of establishment, therefore all forests have accumulated a credit at the time of harvesting and no debt is incurred. The validity of the Lamers et al. (2013) approach depends on the forest owner's intentions and objectives of management at the time of establishment. A crop that has been specifically planted for biomass cannot incur a carbon debt, as the sequestration would not have occurred without the biomass demand.

The challenge for most biomass supply chains is the timescale of forest management activity and decision making. Forests can take many decades to grow, during which time markets and ownership objectives can change. In most cases, at the time of harvesting, the owner will have a range of options regarding whether to harvest and where to sell the timber, options that may not have been available at the time of planting. Each option can have a very different impact on forest carbon, future sequestration potential and carbon stored in solid wood products. Therefore, setting the baseline at the point of harvesting has become the most common basis for calculating the carbon impact of biomass demand, as this is the point at which the owner will make an irreversible decision. There is also the question of whether it is most accurate to consider the calculation of biomass impact on forest carbon for each individual tree, at a stand level or at a landscape level. The landscape level approach assumes a region or supply basin that has multiple stands of trees in a perpetual cycle of growth, harvesting and regeneration (either by planting or natural regeneration).

Determining the correct forest management reference level for an entire country has also been one of the greatest areas of contention in establishing the UNFCCC reporting basis. The forest resource, age class structure, management objectives, growth rates and market dynamics are different in every country. Therefore, agreeing a uniform baseline and compliance period against which every country must report can be a considerable challenge. Yet this is a key influencing factor in determining whether and when a bioenergy scenario becomes carbon beneficial (Lamers et al., 2013).

In a report for the European Commission (Agostini et al., 2013) it was argued that the assumption of carbon neutrality is not valid since the harvest of wood for bioenergy causes a decrease of the forest carbon stock, which may not be recovered in a short time, leading to a temporary increase in atmospheric CO2. This stand-based approach has been contested by many who argue that the impact on forest carbon should only be considered at a landscape level, for example the research by Jonkers (2012) and Matthews (2014) as discussed below.

Jonker et al. (2012) considered a landscape level approach in the US South and concluded that in some scenarios, where plantations already exist in multiple mixed age classes, carbon debt is non-existent. Jonker's view was supported by UK Forest Research (Matthews et al., 2014), suggesting that the growth of the remaining mid-rotation stands across the landscape will compensate for any short-term loss of carbon at the point of harvesting. Whilst theoretically true, the critical flaw in the landscape approach is the absence of counterfactual modelling. A comparison of what would have happened in the forest in the absence of biomass demand. Ter-Mikaelian et al. (2015) also supported the argument that the counterfactual should always be evaluated when considering the climate impacts of biomass and that it can lead to either positive or negative outcomes.

Stephenson & McKay (2014) attempted to model a range of counterfactuals and biomass supply scenarios in a study commissioned by the UK government. The model attempted to calculate the carbon payback times for a variety of biomass feedstock types and scenarios in North America, producing generally unfavourable results for the biomass sector, even when compared to coal combustion. The results were contentious, championed by the anti-biomass lobby and refuted by those in the forest industry and biomass sector. A follow up report was commissioned by the UK government (Howes et al., 2016) which included extensive stakeholder consultation on all sides of the debate. In conclusion, it was found that many of the scenarios and assumptions used in the original model were unlikely to occur in practice, and therefore the modelling results were entirely theoretical and not reflective of real-life scenarios in biomass supply chains. The model did show that where biomass demand influences forest management practice (e.g. changing rotation length, changing species or changing management objectives and the end use of timber), this can lead to negative climate outcomes. However, this form of modelling and analysis can only ever be theoretical and cannot genuinely reflect the real-life impact of biomass, the actual counterfactual in every biomass supply scenario can never be determined, therefore modelling will always be inherently flawed. The results of this work left regulators, stakeholders and those in the biomass sector in a difficult position, with uncertainty around the carbon implications of biomass use. There is a general acceptance that some types of biomass could lead to negative climate impacts (e.g. if sourcing biomass from high carbon primary forests). There is also agreement that some types of biomass can lead to immediate positive climate impacts (e.g. when the counterfactual is burned as waste with no energy recovery). Most feedstocks in current use do not fall into these extremes of the spectrum. Many feedstocks are from thinnings or low grade roundwood from commercial forests as a by-product of saw-timber production. Or they are mill residues from the processing of saw-timber (e.g. sawdust, wood chips, bark and off-cuts). These feedstocks could have both positive and negative climate impacts depending on a range of scenarios and assumptions.

To clarify these grey areas and model some scenarios that are more realistic to real life supply chains, Matthews et al. (2015) carried out extensive research and modelling for the European Commission. The aim was to predict the potential impact of biomass demand on the climate. The Matthews et al. (2015) modelling work also deliberately included a range of unrealistic scenarios to demonstrate the potential negative impacts that could occur from unregulated biomass demand. As a consequence of including such extreme examples in the modelling, the results of the analysis became difficult to interpret objectively. Each side of the debate could point to results that supported their case, especially in the absence of clear evidence detailing actual counterfactual scenarios and impacts from real life supply chains.

To bring greater clarity to the analysis and inform regulators with policy recommendations, Matthew et al. (2018) revisited the modelling analysis, once again including examples of both good and bad biomass but providing some clearer examples of the types of feedstocks and forest types that can lead to each pathway. The modelling included the identification of small or early thinnings as delivering a decrease in GHG emissions and a recommendation to strongly favour the supply of forest bioenergy as a by-product of wood harvesting for the supply of long-lived material wood products (e.g. saw-timber production).

Other academics have attempted similar modelling exercises. Sterman et al. (2018) produced a paper highlighting negative impacts from a selection of biomass scenarios. The main contribution of the Sterman et al. (2018) analysis was to demonstrate the complexity and variability of counterfactual modelling and that the output and results are entirely dependent on the input assumptions. Where these assumptions are invalid, or not representative of realistic scenarios, the results will be misrepresentative. It was not the intention of the study but the findings and assumption of the work have been widely challenged. Prisely et al. (2018) highlighted some of the weaknesses in the Sterman et al. (2018) report, especially the choice of unrealistic assumptions in the modelling. The Prisely paper was followed by further analysis by Rolls & Forster (2020) which challenged the validity of the original findings by questioning the choice of forest management assumptions and counterfactuals; and demonstrating that even a small difference in base assumptions can lead to a large difference in results.

Despite the substantial amount of research, debate, modelling and analysis into the carbon impact of biomass demand, there has been limited consensus and agreement. It is not practical to model every single biomass supply chain for every variable assumption; the combinations are too complex and often unknown. The counterfactual impact of any decision will always be uncertain, a decision of no harvest at one point in time, might be followed by a decision to harvest 6 months later if saw-timber markets or the personal circumstances of the forest owner change, therefore it is not valid to model a no harvest decision as the permanent retention of the carbon stock. Equally, the forest could then suffer a carbon loss as a result of natural disturbance (fires, wind, disease etc.). An original decision to harvest may have resulted in a much higher rate of sequestration and storage in the long term.

Starrs et al. (2018) demonstrated that the risk of wildfire was substantially higher in federally owned US reserved forest (where harvesting and management were restricted), compared to privately owned forests with active management. In California, the risk of wildfire in federal forest (2000-15) was almost double the risk in private forests where both had State firefighting resources. Starrs et al. (2018) found that the risk of fires in federal lands has increased by 93% since 1950-66 (from 1966 onwards), compared to only 33% in non-federal forests. The increased risk is due to a change in forest management practice which began in the 1970s which restricted harvesting practices in federal forests.

Harvesting, by definition, is the removal of carbon from the forest, leading to a reduction in forest carbon stock – this may be short term, medium term or permanent. Reducing forest carbon in this way can be a natural and necessary part of the forest cycle; management intervention emulating the natural cycle of climax, clearance and renewal in a more efficient and productive way. There are many circumstances where a combination of carbon storage in solid wood products, increased growth rates in replacement stands, and the use of by-products and residues to displace fossil fuels will lead to an overall better carbon balance, despite a lower carbon stock in the forest; as demonstrated by the work of Oliver et al (2014) and Favaro et al. (2020). The continual cycle of sequestration, storage in solid wood products, displacement of high carbon materials and regeneration of more productive replacement forest stands offers a better climate contribution than a static stand reaching senescence and emitting carbon through natural causes.