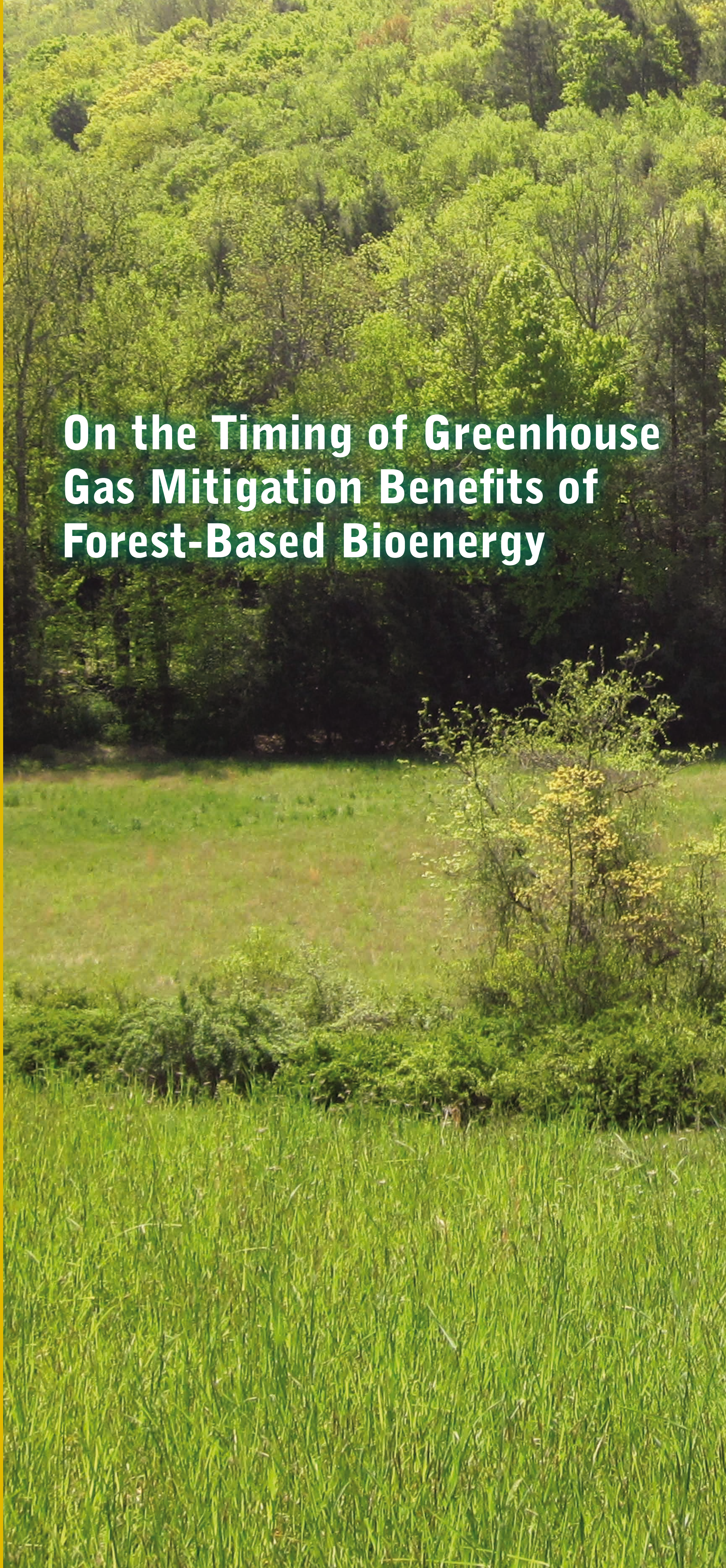
On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy



This statement was prepared by Professor Annette Cowie, University of New England, Australia; Associate Professor Göran Berndes, Chalmers University of Technology, Sweden; Professor Tat Smith, University of Toronto, Canada, with input from other members of Tasks 38, 40 and 43. The statement addresses a much debated issue – the timing of greenhouse gas emissions and carbon sequestration when biomass from existing managed forests is used for energy to displace fossil fuels. The purpose of the statement, which is aimed at policy advisors and policy makers, is to explain the essence of this debate and to propose a perspective that considers the broader context of forest management and the role of bioenergy in climate change mitigation.

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On the Timing of Greenhouse Gas Mitigation Benefits of Forest-Based Bioenergy

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CONTEXT

This statement addresses the issue of the timing of greenhouse gas (GHG) emissions and carbon sequestration when biomass from existing managed forests[i] is used for energy to displace fossil fuels. When a stand is harvested and used for energy the carbon that was earlier sequestered during growth is emitted to the atmosphere, and is again sequestered if the stand regrows. In long rotation forestry, carbon is sequestered by the growing stand for many decades before harvest takes place – and after the harvest it may take many decades before the harvested stand reaches its pre-harvest carbon stock.

The difference in timing between emission and sequestration of forest carbon that is observed on a forest stand level has caused some to express concerns about the climate mitigation potential of forest bioenergy.

In order to fully understand the climate change effects[ii] of bioenergy from existing forests, ***it is important to consider the entire forest landscape and the wide range of conditions within which forest bioenergy systems operate, long term as well as short term effects and climate objectives, and the interactions between human actions and forest growth.*** *Rather than concentrating on the timing of emissions and sequestration, it is more relevant to focus on assessing the contribution that bioenergy from existing forests may make to the establishment of renewable energy systems that can provide a GHG-friendly energy supply into the future.*

BIOENERGY AND GHG ACCOUNTING IN THE CONTEXT OF MANAGED FORESTS

Forest biomass for bioenergy is typically obtained from a forest estate managed for multiple purposes, including production of pulp and saw logs, and provision of other ecosystem services (e.g., air quality improvement, water purification, soil stabilization, biodiversity conservation). A forest estate is a mosaic of stands of different ages shaped by biophysical factors such as soil and climate conditions, historic and present management and harvesting regimes, and events such as storms, fires, and insect outbreaks. Carbon losses in some stands counteract carbon gains in other stands, so that across the whole forest estate in a particular region or country the forest carbon stock fluctuates around a trend line that can be increasing or decreasing, or roughly stable (Fig. 1).

The GHG effects of forest bioenergy should be investigated at the scale applicable to the issue concerned: policymakers act to influence developments at the international, national, and larger regional scale, thus the GHG effects of forest-based bioenergy should be determined across the whole national or regional estate, that is, at landscape scale.

The critical questions for policymakers are: will changes in forest carbon stocks at landscape scale, resulting from bioenergy incentives, affect the GHG mitigation benefits of bioenergy, and the timing of such benefits?

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i This statement pertains to forests that are currently managed for productive purposes (e.g., pulp, timber). It does not consider scenarios involving land use change (e.g. replacing existing forest with short rotation crops), or afforestation. Whether a forest system is managed sustainably requires consideration of a wide range of factors in addition to the forest carbon stock, which together determine a forest's biodiversity, productivity, regeneration capacity, vitality and potential to fulfil relevant ecological, economic and social functions. However, considerations beyond carbon emissions and removals are outside the scope of this statement.

ii In addition to their direct effects on greenhouse gas emissions and sequestration, bioenergy systems affect the climate through: (i) climate forcing related to particulate and black carbon emissions from small-scale bioenergy use, and changes in surface albedo; and (ii) indirect effects resulting from bioenergy use, such as price effects on wood and petroleum markets influencing consumption levels and investments in the forest and petroleum sectors and in various other sectors that are sensitive to biomass and petroleum prices. This statement focuses on direct GHG emissions and removals.

The answers vary between different locations, due to variation in environmental and socio-economic factors: the change in forest management and harvesting regimes due to bioenergy demand depends on forest type, climate, forest ownership and the character and product portfolio of the associated forest industry; the forest carbon stock response to changes in forest management and harvesting in turn depends on the characteristics of the forest ecosystem; and the character of existing energy systems determines the fossil fuel displacement - and thus the GHG savings - achieved from bioenergy use. For example, displacing coal achieves greater GHG savings than displacing natural gas, because coal is a more GHG-intensive fuel.

The design of the GHG accounting framework has a strong influence on the calculated GHG savings. The definition of the "without bioenergy" reference scenario, against which the bioenergy scenario is evaluated, is critical. This reference scenario may include forest management for a different mix of products and services, or reserving the forest for conservation.

Choice of spatial and temporal system boundaries will also influence the calculated GHG savings.

For example, in a bioenergy scenario where logging residues are collected and used for bioenergy, the forest carbon will be retained in the forest for shorter periods than under a reference scenario where these residues are left in the forest to decay. This difference in timing of carbon emissions between the reference and bioenergy scenarios is a critical factor determining whether or not forest bioenergy is found to contribute positively to climate change mitigation.

From the stand level perspective, the collected logging residues will be accounted as a carbon loss from the stand, i.e., GHG emissions. If a short time horizon is used, and if the GHG accounting starts at the time of the residue collection, such an evaluation may find that the use of forest residues causes increased GHG emissions compared with the reference scenario over the evaluation period. However, considered at the larger forest landscape scale, gradual implementation of residue collection at logging sites will have a small influence on how the total forest carbon stock (sum of carbon in trees, soil and litter) changes. Accounting at the landscape scale integrates the effects of all changes in the forest management and harvesting regime that take place in response to bioenergy demand. Taken together, these changes may have a positive or negative influence on the development of forest carbon stocks as a whole.

FOREST MANAGEMENT AND HARVESTING INFLUENCES CARBON STOCK

Forest owners plan their management and harvesting regimes based on expectations about future markets for bioenergy and other forest products. The forest carbon stock response depends on the characteristics of the forest ecosystem and on the specific changes in forest management that are implemented.

If bioenergy demand causes forest owners to change their forest management and harvesting regimes so that the forest carbon stock across the whole forest landscape becomes greater than it would have been in the absence of the bioenergy market (e.g. through fertilization, site preparation, and restocking to higher densities and with species/varieties of greater mitigation potential), the GHG mitigation benefit of the bioenergy system is enhanced (Fig. 1a: green line; Fig. 1b: green and purple lines). On the other hand, if changes in forest management and harvesting regimes cause a reduction in carbon stock across the whole forest landscape, the mitigation benefit of the bioenergy system is diminished. The following situations may occur:

- If the forest carbon stock decreases (Fig. 1; red line), this is equivalent to GHG emissions – or a "GHG" cost" – that must be compensated through avoiding fossil fuel emissions, before the bioenergy system begins to produce GHG mitigation benefits. The GHG cost is equal to the difference in landscape forest carbon stock between the bioenergy and reference cases.
- Alternatively, if the forest carbon stock increases, but at a slower rate than it would have increased in the absence of the bioenergy market (Fig. 1c: red line), some GHG accounting approaches equate this with GHG emissions, reducing the GHG mitigation benefit of bioenergy. As there are no actual net emissions, because the forest carbon stock has not decreased, this should be understood as "foregone carbon sequestration".
- If the foregone carbon sequestration in the bioenergy scenario is greater than the GHG emissions savings from displacing fossil fuels, then the net GHG emissions in the bioenergy scenario will be greater than in the reference scenario, in which no bioenergy capacity is developed. The relative advantage of the reference scenario may however be temporary due to diminishing carbon sequestration capacity over time, because growth slows as forests approach maturity.

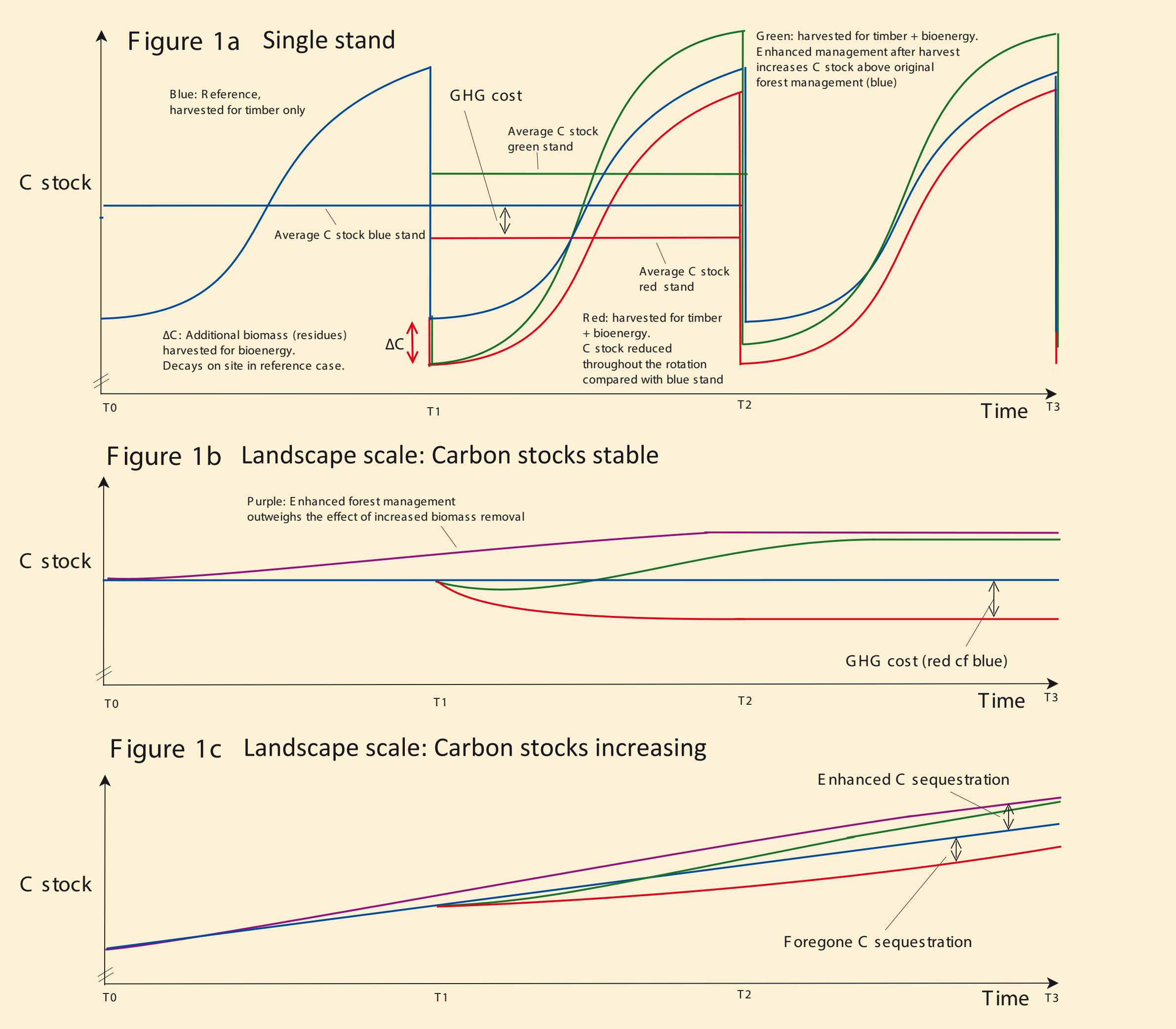

Figure 1 shows simplified representations of the carbon stocks in a managed forest. It does not show changes in rotation period or the carbon stock fluctuations around these simplified curves caused by climate variation and forest operations such as thinning.

Figure 1a shows the carbon stock (sum of carbon in trees, soil and litter) of an individual stand, over successive rotations. The blue curve shows the reference scenario, a forest harvested for timber only. The other curves show two alternative scenarios, in which harvest residues (branches and tops), usually left in the forest, are removed for bioenergy at harvest, at time T1 and each successive harvest. The concept of "GHG cost" is illustrated in the red curve: the average carbon stocks are lower compared with the blue stand, due to removal of harvest residues, and, possibly, flow-on effects on soil carbon stocks and forest growth rate. The green curve illustrates how enhanced forest management can reduce the GHG cost.

Figures 1b and 1c show the total carbon stocks summed across a landscape of multiple stands at different stages in the rotation cycle, assuming that all stands follow either the blue, red or green curves from Figure 1a. In reality, the forest carbon stock on the landscape level will reflect a mix of different management approaches applied to different stands, which may include adjustment to the rotation period. An additional curve, in purple, shows a scenario where changes in forest management across the forest landscape outweigh the effect of increased biomass removal for bioenergy, so that the forest carbon stock increases on landscape level.

Figure 1c shows a situation where the carbon stocks across the landscape are increasing, such as where the national estate is dominated by young stands; over time, the total carbon stocks increase as these stands mature. Although the total stocks continue to increase in all scenarios in Figure 1c, biomass removal can lead to "foregone sequestration" (red curve), though this can be reduced or avoided through enhanced forest management (green and purple curves). Be reminded that the net GHG mitigation of associated bioenergy systems also depends on the GHG displacement efficiency; i.e., a bioenergy system that is associated with declining forest carbon stocks (red curve) can deliver higher GHG mitigation than another bioenergy system that is associated with increasing forest carbon stocks (green or purple curves) if the latter has much lower GHG displacement efficiency.

THE ROLE OF FOREST BIOENERGY IN CLIMATE CHANGE MITIGATION

When biomass is used in place of fossil fuels, GHG emissions associated with the displaced energy system are avoided. The mitigation value reflects the net effect of avoided emissions, and the GHG cost, if any. In situations where there is a GHG cost, if the magnitude of the GHG cost is smaller than the fossil fuel emissions avoided by the bioenergy system, there will still be an immediate benefit, partly reduced by the GHG cost. However if the GHG cost is greater than the fossil fuel emissions saved, this will cause initial net GHG emissions, delaying the GHG mitigation benefits until the time when the cumulative GHG emissions avoided are greater than the GHG cost (Fig. 2).

In situations where the "GHG cost" causes a delay in delivering GHG mitigation benefits, the delay may be less than one year, e.g., if rapidly decaying residues are used in bioenergy systems with high GHG displacement efficiency, but can also be many decades, e.g. if harvest intensity is substantially increased in slow growing forests containing large carbon stocks.

Where a "GHG cost" causes a delay in delivering GHG mitigation benefits this can be considered a drawback from the perspective of near term GHG targets. However, it can also be considered a CO_2 investment, undertaken to establish a renewable energy system. Many other renewable energy options also require a CO_2 investment in their establishment; it should be kept in mind that near-term GHG targets are only a means for inducing the far-reaching energy system transformation that is needed to meet the long-term objective to keep the increase in global temperature below 2°C, as agreed in the Copenhagen Accord. The "GHG cost" needs to be assessed considering also the wider environmental, social and economic costs of investing in bioenergy vs. other energy supply options, which might be renewable, fossil or nuclear.

Decisions on forest management must reflect multiple objectives, covering environmental and socio-economic goals. The overarching priority of forest management is obviously to preserve the forests as a renewable resource, i.e., to ensure that the productivity of the forest system is maintained or improved. Decision-makers should be cognisant that bioenergy provides renewable energy and therefore offers a beneficial alternative to fossil fuels. In contrast, forest management to sequester carbon, without mitigation through avoided fossil fuel emissions, has declining mitigation value over time because carbon sequestration diminishes as forests approach maturity, is vulnerable to future reversal through fires, storms and insect attack, and it does not offer a beneficial alternative to fossil fuels.

Forest management is dependent on economics and policy: a market for bioenergy, which may be created by policy, may stimulate investment in forest management, which in turn may enhance productivity compared with a reference scenario without bioenergy demand. Generally, the GHG mitigation benefit of a bioenergy system can be improved through: (i) forest management practices that enhance forest productivity; (ii) minimization of process chain emissions; and (iii) efficient use of biomass to displace GHG-intensive products and fossil fuels, including cascading use of forest products to displace GHG emissions repeatedly before final use for energy.

Increased demand for biomass would increase the pressure on forest resources, so good governance is required to safeguard conservation areas and ensure sustainable forest management. For example, legislation could impose mandatory prescriptions for forest regeneration after harvest (which can be expected to enhance the carbon stocks across the landscape compared to a situation without such legislation).

From the perspective of global temperature targets, scientists have estimated a concentration of atmospheric GHGs that should not be exceeded. The difference between current concentrations and this threshold can be considered the atmospheric capacity for GHG emissions – the "emissions space". Uncertainty about climate sensitivity, bio-geophysical feedback mechanisms, and feasibility of "negative emissions" technologies, prevent exact quantification of this emission space. But the critical question of how society should make use of the remaining emissions space should be addressed from a strategic point of view today.

Fossil energy infrastructure continues to expand around the world and, given the long lifetime of energy infrastructure, this implies considerable claims for emission space. It is urgent to shift energy sector investments away from fossil fuels and focus on the full suite of renewable energy options that will all be needed if we are to reach the 2°C target. But it needs to be noted that the establishment of new non-fossil energy technologies and associated infrastructure may also occupy part of the emission space, as fossil fuels will be used for the construction and operation of new energy systems. Similarly, some level of forest carbon stock reductions associated with bioenergy expansion may be an acceptable – and possibly temporary – consequence of the establishment of an industry capable of providing renewable energy services for the world.

Design of policy for forest-based bioenergy should balance near-term GHG targets with the long-term objective to limit the increase in global temperature to 2°C, and should be based on a holistic perspective recognizing the multiple drivers and effects of forest management. Otherwise, there is a risk that policies will fail to promote outcomes that simultaneously address production and conservation objectives. Policy should be devised to promote the optimal use of land and biomass resources to meet needs for food, materials and energy.

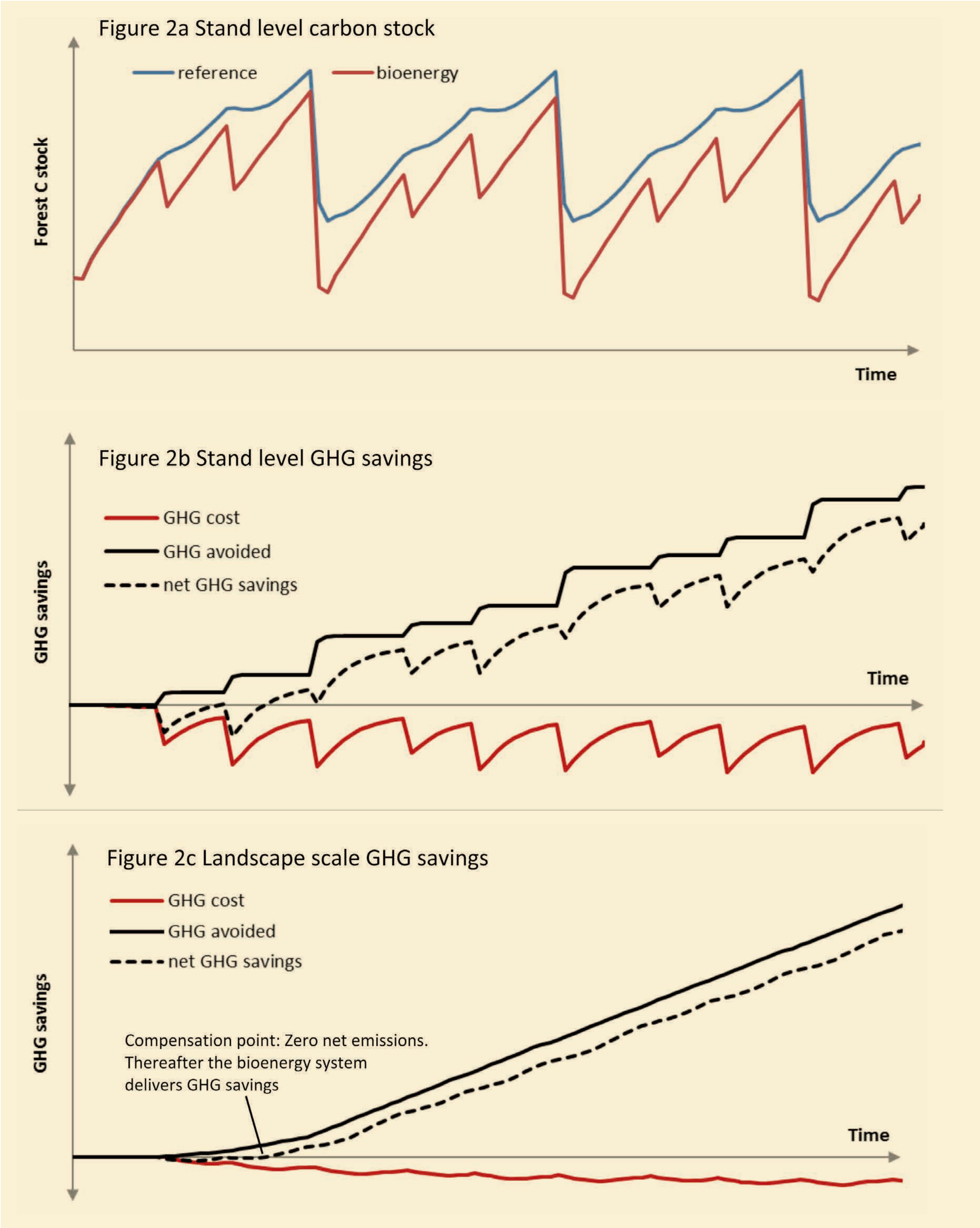

Figure 2 illustrates the timing of GHG savings in a case where there is a GHG cost, using the example of a stand that is thinned twice before final harvest, and where thinning and harvest residues decay slowly on-site in the reference case.

Figure 2a shows the carbon stocks (sum of carbon in trees, soil and litter) at stand level in the reference and bioenergy cases.

Figure 2b shows the GHG savings from an individual stand as the biomass removed from the forest is used for energy products, and Figure 2c shows the GHG savings summed across a landscape comprising multiple stands at different stages in the rotation cycle, assuming that all stands follow the red curve from Figure 2a.

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Further Information

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