BIOMASS CARBON ACCOUNTING

A Report Commissioned by the Independent Advisory Board of Drax Group PLC

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The views expressed in this report are those of the author and do not necessarily reflect the views of the Independent Advisory Board (IAB) or Drax PLC.

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1. Background & Aims

Bioenergy is one of the alternatives to fossil fuels in the shift towards a zero-carbon economy. However, the development of bioenergy systems at scale has frequently been challenged in terms of its carbon benefits and externalities.

In 1998, shortly before his death, the late Professor Hall, one of the co-founders of the Intergovernmental Panel on Climate Change (IPCC) and an advocate for realisation of the global bioenergy potential, summarised the conditions that must be met for bioenergy, including forest based biomass, to make an important contribution to the displacement of fossil fuels:

"The potential resource for bioenergy is large... Therefore, we expect biomass to be an important fuel of the future, but this cannot be taken for granted. The systems adopted must demonstrate clear environmental and social benefits relative to alternatives if the potential is to be realised. These benefits are not inherent to biomass energy but depend on site- and fuel cycle-specific factors. Life-cycle analysis and evaluation of external costs are important means for assessing the social and environmental pros and cons of bioenergy systems."[1]

The aim of this assignment was to explore and clarify the carbon accounting frameworks used to describe the emissions associated with the production and consumption of wood-based bioenergy, in particular biomass from forests as opposed to material obtained from agriculture, waste or short-rotation coppices.

This report is divided into three parts:

Part 1. Provides an introduction to carbon accounting concepts and principles used for forests and forest products, including bioenergy. Starting with a historical perspective it introduces the concepts of stocks and flows and compares forest carbon accounting with the accounting of emissions from fossil fuels.

Part 2. Provides greater depth into accounting frameworks at the national level and different approaches to the Life Cycle Assessment of forest products.

Part 3. Discusses ways in which current carbon accounting frameworks can be used to measure and improve the benefits of forests and forest product policies, including the use of bioenergy. It addresses potential challenges to accounting frameworks and suggests potential solutions to some of the issues raised by organisations concerned with potential negative impacts of bioenergy.

[1] D.O Hall, J.I Scrase, Will biomass be the environmentally friendly fuel of the future?, Biomass and Bioenergy, Volume 15, Issues 4–5,1998.

2. Basic Concepts in Carbon Accounting for Biomass

This section introduces concepts used in carbon accounting for biomass production and consumption along with some historical perspectives that shed light on the way the accounting frameworks have been developed.

2.1 Historical Background

Wood and charcoal from forests were the primary source of energy for human settlements and early industry until the production of coal at large scale from the 18th century onwards.

Forests have been multiple-use resources from early times and efforts to manage them have been features of civilisations from the Romans in Europe, the Han in China to the Ming in Japan. From Norman to Tudor times many of the forests in Britain and Europe were under Royal control, reserved for hunting and timber revenues. The first documented example of planned forest management for sustained yield comes from 13th century Portugal, where a Royal Forest was established to prevent coastal erosion, reduce soil degradation and produce naval timber. From 1500 onwards forests became increasingly managed to supply timber for maritime and urban construction. With industrialisation, coal replaced woodfuel and iron ships replaced timber craft; so, forest management and planting shifted towards conifer species suited for pit-props, canal and railway sleepers.

Today's managed forests remain multipurpose resources with products ranging from construction timber, fibre board, paper products, biomass for energy and services such as recreation and flood prevention.

Throughout history, fuelwood has been an essential component of forest production, with a hierarchy of value determining which outputs are used for material versus energy ends. Fuelwood is usually at the bottom end of the hierarchy - what is left over after more valuable materials have been selected and processed.

In recent times wood fuel markets have become more sophisticated, with a growth in the demand for uniform, high quality wood fuels, giving a cleaner, more consistent burn, suitable for industrial and domestic applications. This demand has led to a shift in the fuel market towards industrial wood pellets and high-grade wood chips. With the exception of short rotation coppices, forests supplying these wood fuels remain multipurpose.

2.2 Climate Change and Ecosystems

Anthropogenic climate change is the result of human activities that took-off during the industrial revolution and accelerated throughout the 19th and 20th centuries. These activities, initially the large-scale exploitation of coal, followed by oil and gas, caused the concentrations of carbon dioxide in the atmosphere to rise from a pre-industrial level of around 280 ppm[2] to over 350 ppm by 1990 and passing 410 ppm in 2020. Land-use change, notably the conversion of high carbon stock forests in the tropics to agricultural land contributed between 10% and 30% of the rise in atmospheric carbon dioxide[3]. Most of this change has been driven by demand for food production but with complex social, governance and economic interactions relating to land tenure, infrastructure development and social

[2] ppm = parts per million.

[3] Houghton, R.A., 2005. Tropical deforestation as a source of greenhouse gas emissions. *Tropical deforestation and climate change, 13.*

changes playing an important part in the process[4].

Human induced flows of carbon to the atmosphere from the combustion of fossil fuels and land use change are superimposed on a natural carbon cycle driven by photosynthesis and respiration - the biological carbon cycle.

The biological carbon cycle (uptake of carbon by terrestrial and aquatic plants and releases from respiration and combustion) is not considered a contributor to anthropogenic climate change although there are some grey areas: many terrestrial ecosystems, such as forests and phytoplankton, have increased their rate of removal of carbon dioxide from the atmosphere as a result of nutrient deposition and elevated concentrations of CO_2 in the atmosphere. Terrestrial ecosystems have sequestered approximately 25% of anthropogenic CO_2 emissions since the 1960's[5]. This sequestration currently acts as a brake, helping to slow the rise in atmospheric carbon, but there are concerns that climate and direct human impacts on ecosystems could see this brake fail or go into reverse which would result in a climate tipping point.

Carbon flows to the atmosphere resulting from human disruptions to the biological cycle, such as deforestation (a change in land use from forest to non-forest) and degradation (loss of carbon stock from land that stays in the same land use category), are included as anthropogenic greenhouse gas emissions, contributing to climate change, but flows to the atmosphere that are part of a stable or continuous use system, such as the flow of carbon into crops through food chains and returning to the atmosphere through animal[6] and human respiration, decomposition and combustion are considered part of a neutral cycle.

2.3 Stocks and Flows of Carbon in Forests

Forest carbon accounting is based on an understanding of the flows of carbon between different stocks denoting components of the forest ecosystem, the atmosphere and harvested products.

Figure 1 shows a simplified version of a stock - flow model, with carbon flowing from the atmosphere into the stock of forest biomass - trees (this flow is sometimes shown as a single arrow - the net between photosynthesis and respiration or a double arrow to separate each component). Within the forest ecosystem there are transfers of carbon from living matter to deadwood and litter and to soils. Soils are sometimes overlooked but are of critical importance as in most temperate and boreal forests they represent a larger and more stable stock of carbon than the trees. While soil carbon is generally more stable (slower to increase and more resistant to loss) than the above-ground stock it can nevertheless be depleted rapidly through disturbance such as ploughing or draining which is a feature of some management practices. Once ploughed or drained, large carbon stocks held in peat soils are susceptible to loss through oxidation and burning. There is ongoing research regarding the potential loss of soil carbon in different soil types relative to carbon uptake by woody biomass when different types of grassland and moorland are converted to forestry.

Material extracted from the forest is represented as a flow to a stock of harvested wood products. The stock of harvested material within a given region may grow or shrink depending how timber is used within the economy, for example the proportion used in long-lived end uses such as construction relative to that going to short-lived uses such as

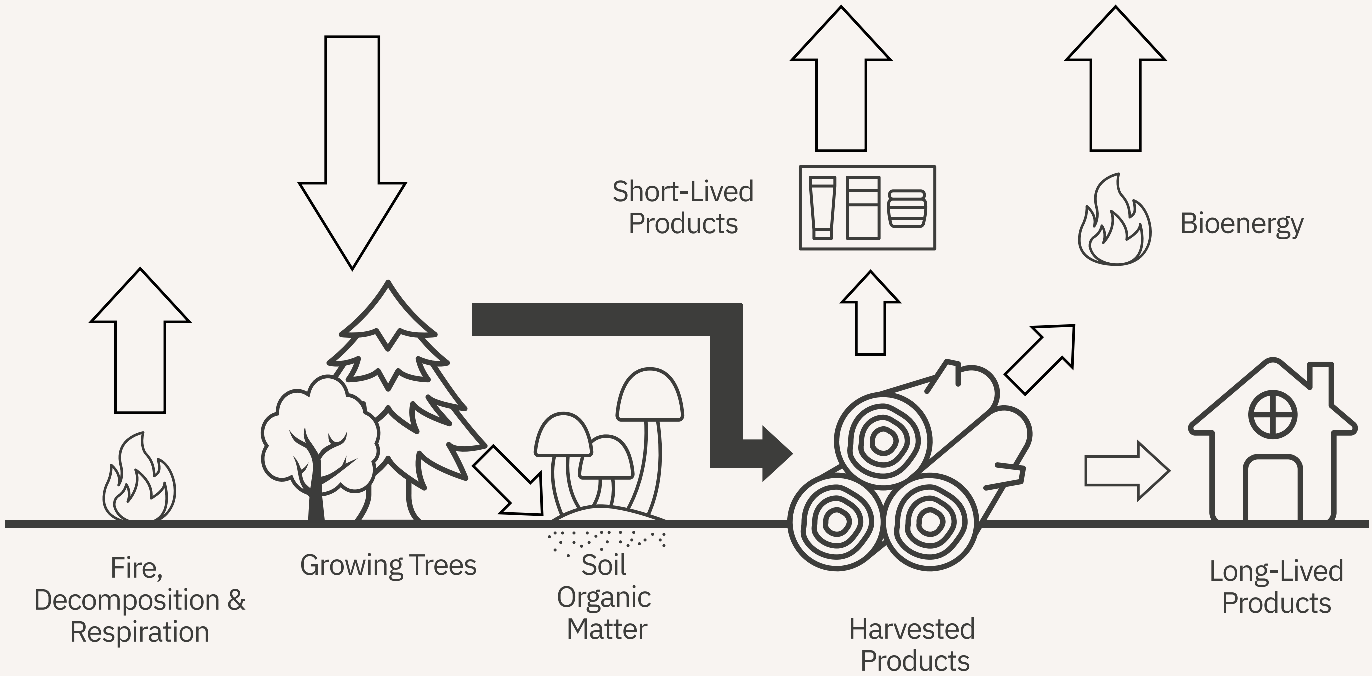
[4]Kissinger, Herold & De Sy, 2012. Drivers of Deforestation and Forest Degradation. Report for DECC.

[5]Le Quéré, C., et al. (2014), Global carbon budget 2014, *Earth Syst. Sci. Data Discuss.*, **7**, 521–610, doi:10.5194/essdd-7-521-2014.

[6]While the CO_2 from domesticated animal respiration is excluded from anthropogenic emissions, the methane component is included.

paper, cardboard and bioenergy[7]. The use of biomass or decomposition of short-lived (and eventually the long-lived) materials is represented by a flow back to the atmosphere. It should be noted that where decomposition occurs in anaerobic conditions, such as in landfill sites or piles of biomass, some of this return flow to the atmosphere will be in the form of methane, a more powerful greenhouse gas than CO_2. In addition to these flows there may be occasional sudden returns to the atmosphere from events such as forest fires that deplete the stocks in large areas of forest.

Figure 1. Stocks and Flows of Carbon in Forests and Harvested Products



The rate at which forests and harvested products accumulate or lose carbon depends on the following flows, relative to the uptake by photosynthesis (growth):

<u>Deforestation / Afforestation:</u> the conversion of forest land to other land uses with lower carbon stocks or afforesting of non-forest land.
<u>Degradation / Enhancement:</u> the loss of carbon stocks and productivity resulting from over-extraction or factors such as fire and pests. Enhancement, when the rate of extraction is lower than the rate of growth.
<u>Losses or gains to the stocks of harvested products:</u> increases or decreases in the rate at which wood products held in long-term products such as buildings are lost relative to inputs of newly harvested material.

[7] https://www.pnas.org/content/116/29/14526

Box 1: Would forests continue to accumulate carbon if they were left unharvested?

This depends on the type of forest and other factors such as soil, climate and elevation.

There is evidence that many natural or semi-natural forests in the tropics and temperate regions could, if harvesting and thinning ceased, continue to sequester carbon in the soils over millennia, particularly in areas of high rainfall, where soil respiration is lower than the annual inputs from litter and deadwood. In these forests, the tree component of the ecosystem can be considered like a pump of carbon from the atmosphere into the soil[8].

However, many forests, in particular plantations and stands that have been planted with a view to wood production, are limited in terms of their sequestration potential as once they exceed certain heights or when they accumulate large loads of deadwood, they become prone to fire, windthrow and diseases. In most production forest situations, managing for optimal carbon storage entails extraction of biomass (thinning) to reduce overcrowding, fuel load and focal points of disease or pests[9].

If forest harvesting was stopped in these production forests, they would continue to accumulate carbon for a while, but this would be followed by events resulting in large releases of CO_2 from fires or oxidation of deadwood. Restricting the harvesting of existing production forests would also have a negative impact on the business case for establishment of new commercial woodland.

2.4 Sustainable Forest Management

The paradigm of sustainable yield has been central to the education of foresters and the practice of silviculture since the mid-19th century. The growth in international trade associated with colonisation and industrialisation led to timber shortages in parts of the world, so forest management departments were established to monitor and control forest use.

Sustainable yield is the concept of ensuring offtake from a natural system remains at or below the level of reproduction of the resource. The concept is simple to grasp but can be complex to put into practice in specific areas and relates to the ecological conditions and management objectives within particular regions in specific management areas.

The scale at which forest management is viewed will determine whether the stock of carbon in the growing biomass is maintained or fluctuates over time as different areas are harvested and regrown.

When a managed forest covers several square kilometres[10] it is likely that the extraction of timber from compartments harvested in any one year will be at or below the increment in the unharvested area. However, when looking at smaller land units such as plantations or woodlots planted on individual farms, the biomass change over time will look like a saw-tooth at the farm-level.

Forest management on smaller units is generally still considered sustainable as long as there is a plan to re-establish trees following each harvest and as long as there is no systematic decline of productivity across an area due to factors such as soil erosion or nutrient depletion.

In terms of carbon management, there has been an increase in the awareness of soils as a stock of carbon that can be vulnerable to release as a result of deep ploughing or drainage. If depleted, soil carbon will recover at a small fraction of the rate of accumulation in the biomass.

[8] Luyssaert, S., Schulze, ED., Börner, A. *et al.* Old-growth forests as global carbon sinks. *Nature* **455,** 213–215 (2008).

[9] Raymer, Ann & Gobakken, Terje & Gobakken, A. (2011). Optimal Forest Management with Carbon Benefits Included. Silva Fennica. 45.

[10] The catchment area of a typical sawmill or pellet mill is likely to be 100’s or 1000’s of square kilometres.

2.5 Production Forests, Natural Forests and Everything in Between

Carbon accounting frameworks for forests and products are designed to cover a wide range of forest management regimes but discussions about bioenergy sometimes neglect this range and focus on archetypal “natural” or “old-growth” forests. This is an area where terminology can be problematic because the concepts of a what constitutes a managed versus a natural or old growth forest varies considerably between countries, and groups of stakeholders[11].

The easiest place to start is at the extremes: monoculture tree plantations versus pristine natural forests with virtually no human interference.

Monoculture plantations are readily identified; they are generally even-aged, monoculture stands that have been planted for timber, pulpwood or woodfuel production. Some of the first tree plantations were established to provide wood for curing crops such as tobacco and tea in the tropics. Just because such plantations are monocultures does not mean they have a single purpose, for example they have often been planned to provide windbreaks or soil protection on slopes in addition to products. Plantations are typically planned and managed with a view to production (harvest) within a certain timeframe and forest authorities are often responsible for checking whether an area can be felled and that it is replanted within a given timeframe.

At the other end of the spectrum, pristine natural forests are now rare in Europe, given that nearly all the forested area has been subject human impacts such as selective logging, extraction of plants or animals within recent history[12]. A study in 2016 found less than 12 million km^2 of intact primary forest, globally, most in remote or protected areas within the boreal and tropical biomes[13].

Between these two extremes there is a continuum of management intensity, ranging from plantations with added elements of diversity, such as patches of natural regeneration around lakes, rivers and roads; and from the other side, mainly natural forests where some management actions such as firebreaks and brush control measures are applied. Forest management regions may contain a patchwork of different management intensities, with compartments of plantation alongside areas set-aside for natural processes.

When considering the effect of wood fuel demand on forest management, it is important to bear in mind the wide range of forest management types. This will be explored further in Section 3.

2.6 Measurement of Carbon Flows

Fundamental differences in the ways that carbon emissions from fossil fuels and wood products are measured underly the distinct accounting approaches taken for reporting bioenergy and fossil fuel emissions.

With fossil fuels, emissions of CO_2 to the atmosphere are calculated from the mass of fuel burned multiplied by its respective emission factor. The amount of fuel combusted in a given period can be accurately determined, by sector or individual business, based on purchasing or consumption records maintained by those businesses. Fossil fuels are transported

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[11] Wirth, Christian & Messier, Christian & Bergeron, Yves & Frank, Dorothea & Kahl, Anja. (2009). Old-Growth Forest Definitions: a Pragmatic View. Old-Growth Forests, 11-33 (2009).

[12]https://www.nature.com/articles/d41586-018-07183-6

[13]http://www.intactforests.org/world.map.html

and processed in relatively few, carefully administered facilities, making the tallying of production and consumption figures straightforward. Changes in the stocks of fossil fuels would be difficult to measure since those are buried reserves.

In the case of forests, the net flows of carbon into and out of the ecosystem are estimated by calculating the differences between periodic assessments of biomass stocks. Losses of biomass stocks (representing emissions to the atmosphere) or gains in stocks (representing removals from the atmosphere) are thus calculated from the changes in stocks between points in time rather than measurement of the flows themselves[14]. This approach is taken because flows of carbon from the atmosphere into the growing vegetation and transfers to different pools within the ecosystem are difficult to measure, whereas methods used to quantify carbon stock changes in forests have been developed over many years for the purpose of planning timber production and making forest management decisions. In recent years these methods have been adapted to account for accumulated carbon, net of growth, mortality and harvesting[15].

While transfers of carbon out of forests in the pool of harvested products can be reasonably estimated from timber industry reports, flows within the pool of harvested material are also hard to track because materials go into many products – timber, furniture, fibreboards, cardboard, paper, packaging, coatings, as well as wood fuel. Wood-based processing and manufacturing facilities are diverse and widely dispersed in the economy. Much of the wood gathered for bioenergy is informally collected and used in residential areas, especially in developing countries. Part of the material available for bioenergy comes from waste recovered during processing – at sawmills, manufacturing and waste processing facilities.

Because of the challenge of tracking wood product flows, the net changes to the stock of harvested wood products are normally estimated by modelling the rate of input versus the rate of decomposition and combustion of different grades of products. Materials such as paper, cardboard and firewood are assumed to be short-lived and return rapidly to the atmosphere, long-lived timber products used in construction are assumed to decay over several decades. When the inputs to the wood product stock is higher than the losses, this gives rise to a removal from the atmosphere and when it is lower, this represents an emission. Figure 2 summarises the different approaches to quantifying emissions and removals for fossil fuels and forests. A more detailed explanation of the differences between fossil fuel and land use change accounting is given by Iverson, Lee and Rocha[16].

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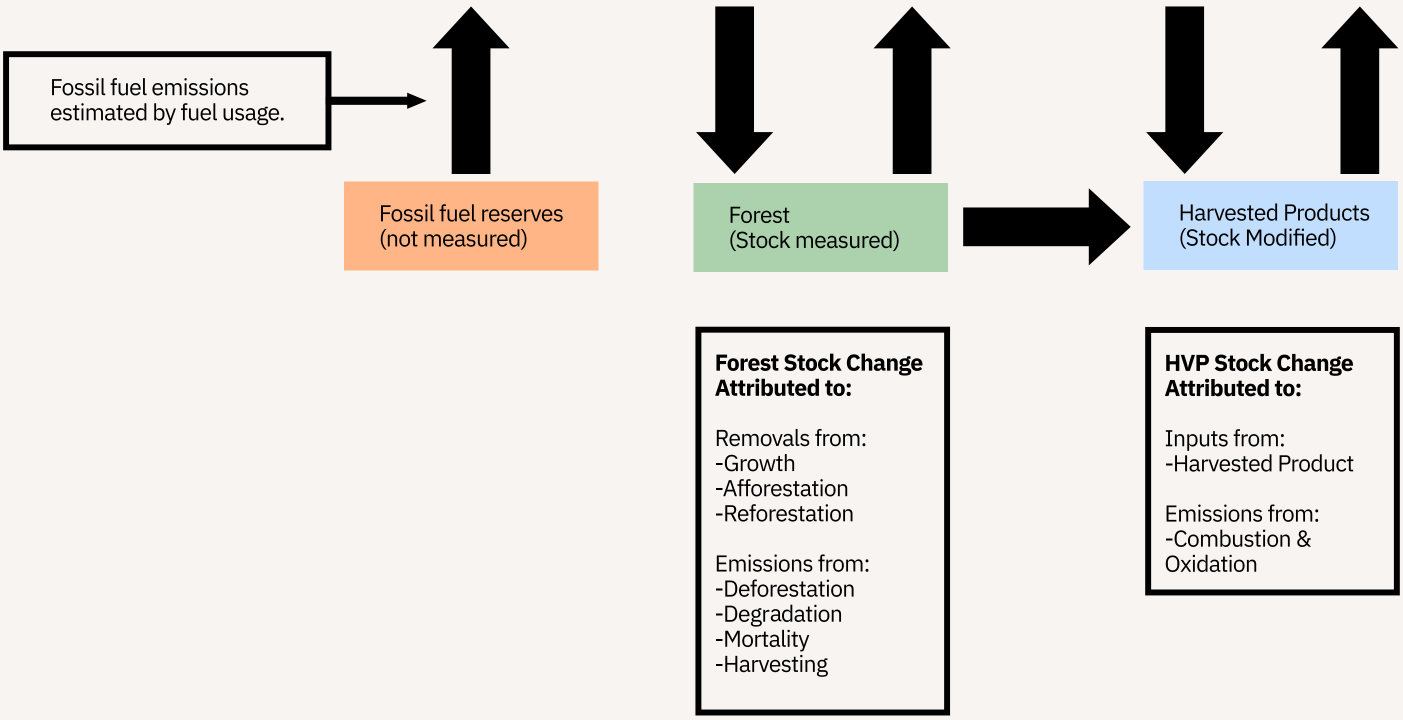
[14]Flux measurement technologies, where a gas analyzer measures the real-time flows of carbon into and out of forests have been developed but these are research tools to understand ecosystem processes and have not been applied operationally by forest industries or governments.

[15]Measurements of components of tree volume are normally carried out within sample plots representing different strata or types of forest. Changes in forest area are measured using mapping techniques, including the use of earth observing satellites.

[16]Understanding Land Use in the UNFCCC (link)

Figure 2. Differences between fossil fuel and forest (and forest product) emissions reporting



2.7 Challenges to the Carbon Neutrality Assumption for Biomass

Carbon Neutral is a much used but imprecise term, referring to a condition where a product or service does not contribute to climate change resulting from the human induced emission of climate warming gases (CO_2, methane, nitrous oxide and other Kyoto gases). Carbon neutrality does not imply zero emissions but implies that emissions to the atmosphere in one part of a process are balanced by removals[17] in another part of the process.

There are other climate influencing factors associated with forests and their management, including albedo, evapotranspiration and emissions of volatile organic compounds but these are not normally considered within the carbon neutrality construct.

Biomass used for bioenergy, along with other biogenic products such as plant and animal biomass used for food and materials, are often considered carbon neutral (apart from the carbon released as methane from enteric and anaerobic metabolic pathways, and emissions from fossil fuels used in transportation and processing) so long as the stocks of carbon within the agricultural, forest systems and the pool of harvested products are not depleted over time. The following challenges to the neutrality assumption have been raised for wood-based energy:

a) Carbon Debt

The term "carbon debt" is not used by IPCC or any greenhouse gas reporting standards. However, the concept has been proposed as a way of highlighting the time elapsed between the combustion or oxidation of harvested material (for bioenergy or other purposes) and the recapture of a similar amount of carbon within the forest[18]. While the term debt assumes that measurement of carbon flows starts at the point of harvest (as opposed to the point of planting or any other time) it has been argued that the use of biomass from long rotation (long debt recovery) systems is environmentally negative because it takes several decades for a similar amount of carbon to be re-sequestered at a given site.

[17] Organisations involved in carbon offsetting have also used emission reductions (reductions of emissions relative to a counterfactual baseline) to achieve neutrality.
[18] A less discussed version of carbon debt is the time elapsed to recover carbon emissions from soils when plantations are established on organic soils various tillage systems.

To better understand the issue of carbon debt it is helpful to compare the carbon dynamics of two contrasting systems – a short rotation coppice, where biomass is harvested on a 3-year cycle (3-year debt recovery) and with a Sitka spruce plantation with a 40 rotation (taken from UK Sitka Spruce Yield tables), with thinning, producing chipped wood, potentially suitable for bioenergy, every 5 years. Thinning is done to enable the stand to produce the maximum amount of high-quality timber at final felling.

While both systems have similar average outputs of biomass on an annual basis, the average stock of carbon held on the land by spruce plantation is around 86 tonnes of carbon. So, while the carbon debt recovery period is longer in the forest system there is a corresponding higher average stock of carbon.

3 Year Short Rotation Coppice Cycle

Y1	Y2	Y3

- Carbon recovery (debt) period 3 years
- Average annual output of system = 4 tC (8 tonnes oven dry biomass / ha)
- Maximum carbon stored in above ground biomass = 24 tC/ha
- Average carbon stored in above ground biomass = 8 tC/ha

40 Year Forestry Cycle

Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Y11	Y12	Y13	Y14	Y15	Y16	Y17	Y18	Y19	Y20
Y21	Y22	Y23	Y24	Y25	Y26	Y27	Y28	Y29	Y30
Y31	Y32	Y33	Y34	Y35	Y36	Y37	Y38	Y39	Y40

- Carbon recovery (debt) period 40 years
- Thinning on a 5-year cycle
- Average annual output of system = 4.25 tC/ha (8.5 tonnes oven dry biomass per ha)
- Maximum carbon stored in above ground biomass = 170 tC/ha
- Average carbon stored = 86 tC/ha

For managed forests carbon debt is inevitable when viewed at the compartment or stand level. However, as one moves from the compartment to forest, region and national levels those recently harvested areas should be balanced out by other stands at different levels of maturity. If the level of biomass extraction increased to an extent that a region experienced an overall reduction in growing stock, this should be picked up by forest inventory data and should be reported as forest degradation. The Intergovernmental Panel on Climate Change emphasises the importance of distinguishing routine forest management from forest degradation resulting from activities such as high grading, overgrazing in open woodlands or human incursion into previously undisturbed forests [19].

[19] IPCC Report on Definitions and Methodological Options for Inventory of Emissions from Direct human-induced degradation of forests and Devegetation of other vegetation types (link).

b) Counterfactual Scenarios

Given that many unmanaged, old growth forests are sinks of carbon as opposed to simply in carbon balance, there is an argument that a neutral cycle from managed forests, even where carbon stocks are kept at a steady average state, represents a net loss of sequestration potential relative to an ideal or optimal management regime. There is an ongoing debate about the extent to which forest management can be optimised to retain and sequester carbon and what role harvesting and use of products should play within this. Modelling studies indicate that when including the potential for storage of carbon in harvested products and the use of bioenergy, the optimal use of forests, viewed purely from a carbon perspective, would include active management as opposed to letting forests revert to some undisturbed natural state [20], [21]. However, the optimal approach is likely to vary considerably between locations and forest types.

c) Broader sustainability factors

Several organisations have pointed out the danger of simply regarding forests and trees as "sticks of carbon". The long-term viability of forests is dependent on maintaining a number of functions and properties including nutrient cycling, biodiversity and arguably economic functions that permit reinvestment in management and renewal. Todd and colleagues at the USDA's Northern Institute of Applied Climate Science provide an excellent menu of forest management recommendation for combining good carbon management outcomes with climate change adaptation, biodiversity and other considerations [22].

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[20] Asante, P. and Armstrong, G.W., 2012. Optimal forest harvest age considering carbon sequestration in multiple carbon pools: A comparative statics analysis. *Journal of Forest Economics*, *18*(2), pp.145-156.

[21] Favero, A., Daigneault, A. and Sohngen, B., 2020. Forests: Carbon sequestration, biomass energy, or both? *Science advances*, *6*(13)

[22] Todd A Ontl, Maria K Janowiak, Christopher W Swanston, Jad Daley, Stephen Handler, Meredith Cornett, Steve Hagenbuch, Cathy Handrick, Liza Mccarthy, Nancy Patch, Forest Management for Carbon Sequestration and Climate Adaptation, *Journal of Forestry*, Volume 118, Issue 1, January 2020, Pages 86–101, https://doi.org/10.1093/jofore/fvz062

3. Accounting Frameworks for Forests and Forest Products

This section discusses how the main carbon accounting frameworks for the production and use of forest-based biomass are structured and used for various purposes.

3.1 National Greenhouse Gas Inventories

Under the UN Framework Convention on Climate Change (UNFCCC), signatory countries are encouraged to report on greenhouse gas emissions using semi-standardised methods that have been designed with a balance of consistency, accuracy, comprehensiveness and practicality in mind. National reporting covers all major economic sectors such as power generation, transportation, and includes agriculture, forestry and land use (AFOLU) [23]. The methods to be used in national reports were developed by the International Panel on Climate Change (IPCC), which published guidelines for national greenhouse gas inventories in 2006 and subsequently refined methods in 2019[24].

The purpose of national reporting is to provide a framework for target setting and the measurement of progress at the national scales and to aid negotiations on agreements to limit the overall levels of anthropogenic greenhouse gases in the atmosphere.

Forest Stock Change

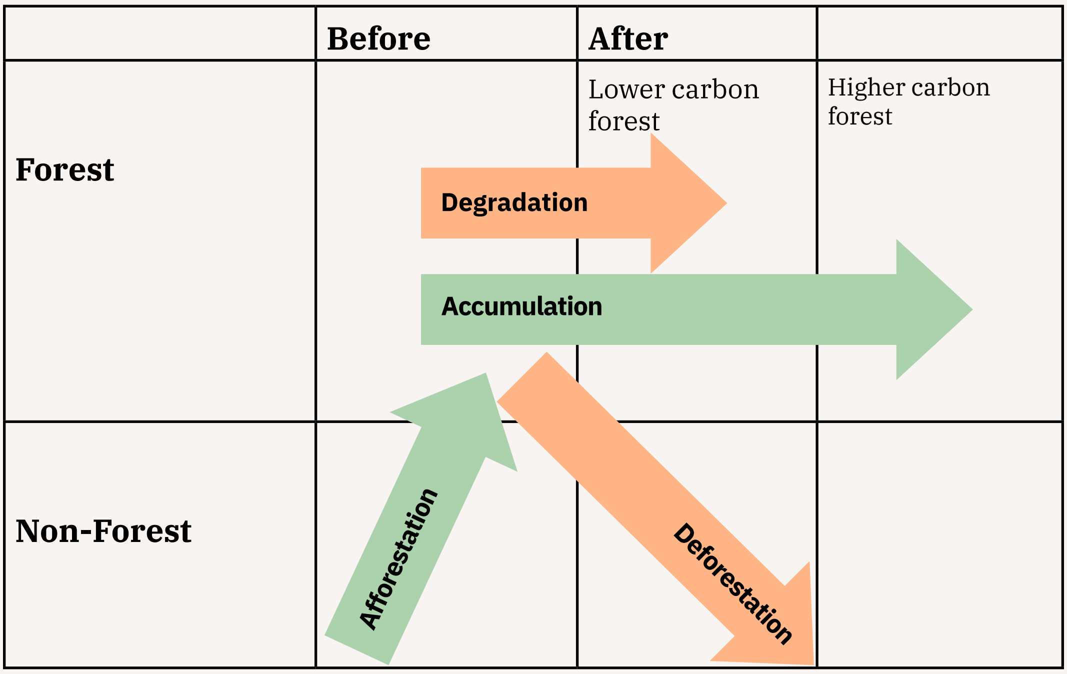
While there are various options and modalities in accounting for forest and harvested product carbon flows under different schemes within the UNFCCC (the Kyoto Protocol, the Paris Agreement and REDD+) the national inventories follow the stock change approach described in Part 1 (2.4.1) and there is a distinction between stock changes occurring in forest that remains as forest (degradation or accumulation) and changes resulting from land use change, where forests are converted to other land uses (deforestation).

Where forest land remains forest but is losing carbon through a process of degradation (where offtake + mortality exceeds regrowth) the emissions associated with this process are reported as an emission from the forest carbon pool. Where forest land is increasing carbon stock as growth exceeds offtake, decay and burning this is reported as a removal of carbon from the atmosphere. Figure 3 summarises the possible processes associated with stock changes and emissions or removals.

[23] Some international activities are excluded such as international shipping, air transport and bunker fuels.

[24] IPCC 2006 Guidelines for National GHG Inventories (link); 2019 Revisions (link).

Figure 3. Land use and land use change processes associated with carbon stock changes. Orange arrows = emissions; Green arrows = removals



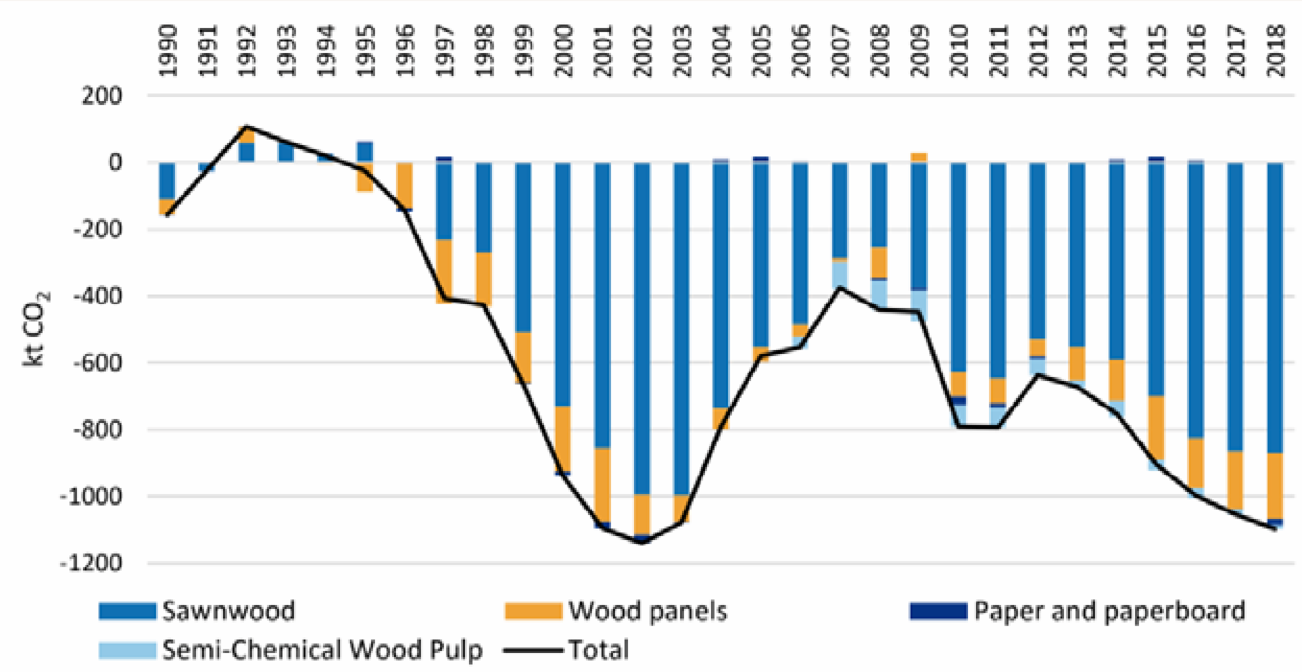
Harvested Products Stock Change

Most countries account for harvested wood products (HWPs) as oxidised at the point of harvest, with no additional emissions beyond those considered as part of the forest stock change calculations. However, inventory guidelines also allow countries to report on changes to the stock of harvested products as a source of emissions or removals.

Where HWP stocks are shown to be increasing – when the accumulation of carbon in long-lived products is higher than the rate of oxidation, then this is counted as a removal from the atmosphere. Where HWP stocks are declining through reduced inputs of long-lived products or increased rates of oxidation then this is counted as an emission. The removal by increasing the stock of HWP is not double-counting stocks of carbon that have been grown in the forest because they have been counted as oxidised at the point of removal from the forest pool through the stock change approach within the forest.

The UK, for example, reported a removal of approximately 2.4 million tCO_2 resulting from a growth in the HWP stock in 2017 (UK National Inventory Report, 2020). Estonia has produced annual estimates of removals and emissions from its HWP stock since 1990 (Figure 4).

Figure 4. Net emissions from HWP categories of Solid wood, Paper and paperboard and Semi-chemical wood pulp in Estonia in 1990–2018, kt CO_2. Note, negative emissions = removals. From Estonian national GHG inventory 2019.



While national inventories report emissions and removals at the national level they do not specifically account for these on a unit of production or consumption basis. Life-cycle carbon accounting aims to provide information on the emissions associated with the production, use and disposal or products. The following sections describe two types of life cycle assessment (LCA) and their potential applications to bioenergy.

3.2 Attributional & Consequential Greenhouse Gas Life Cycle Assessment

Life cycle assessments (LCAs) of products and services aim to provide information on the environmental impacts associated with the production, consumption and disposal of goods and services. Concerns about climate change have led to an increased focus on the greenhouse gas component of LCAs.

There are two main approaches to LCAs – Attributional and Consequential.

<u>Attributional LCAs:</u> where the observed GHG emissions within the supply chain are divided between the units of consumption on a normative or “fair share” basis.

<u>Consequential LCAs:</u> where the impact of incremental or marginal demand on the wider supply system, including substitute products and components, are estimated in terms of GHG emissions per additional unit of product demanded by the market.

The scope of attributional LCA’s tend to cover the operational supply chain of a given product or service – moving along the chain of suppliers, using data from suppliers on emissions per unit of each input or where supplier data is not available, estimating these contributions for each input. Consequential LCA’s take a broader look at the markets supplying inputs and input substitutes and estimate how an incremental increase in or decrease in demand for a given input will result in changes to emissions at a systemic level.

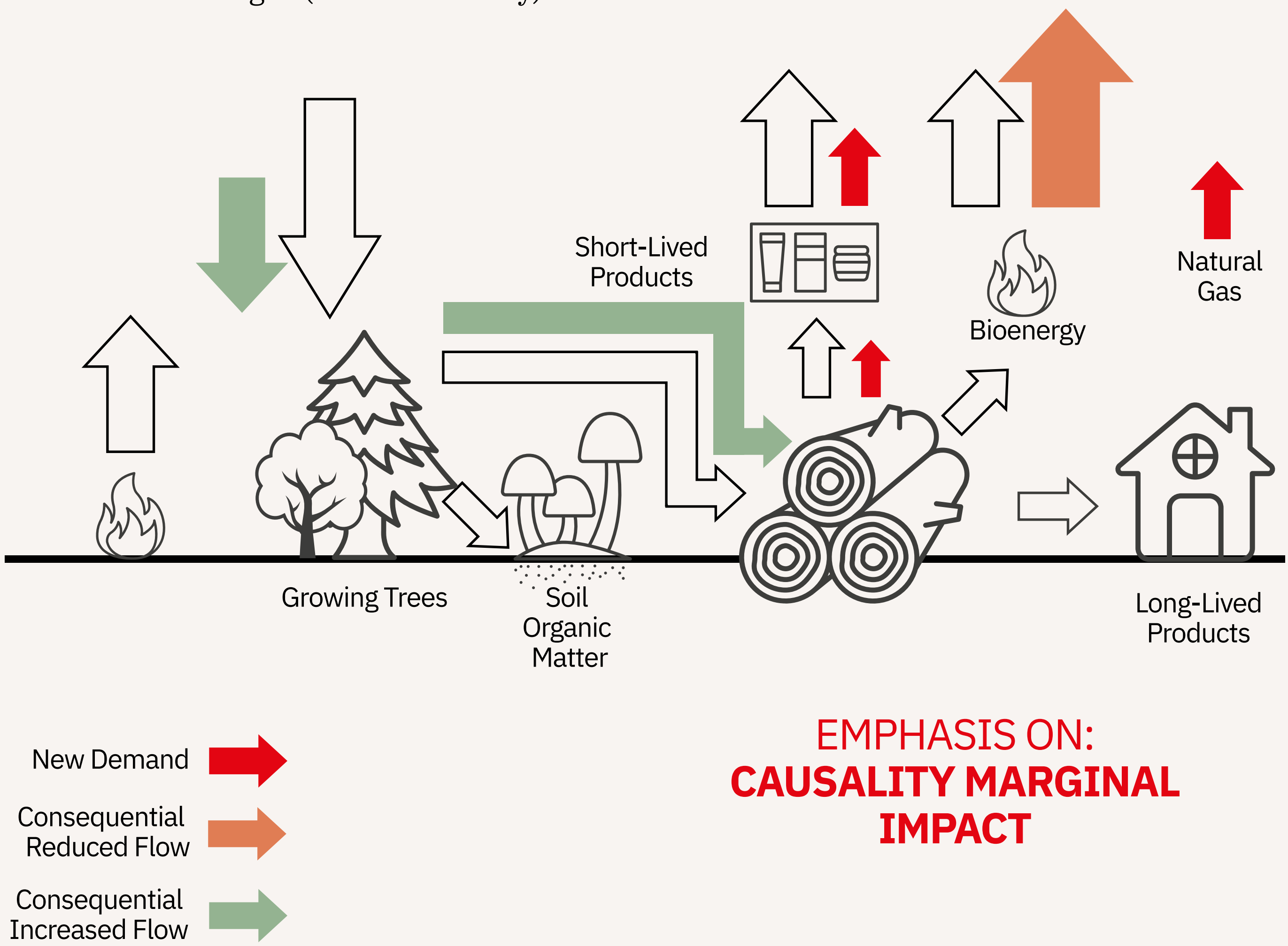
Consequential GHG LCA for Bioenergy

In the case of bioenergy, consequential life cycle assessment is used to assess how a change in demand for biomass will feed through to other parts of the system and forest products economy and how these changes in-turn influence emissions and removals.

Consequential LCA models vary in their scope, design and key assumptions and may arrive at different conclusions, particularly when the system is complex. This is the case when models make inferences about product substitution and demand response processes across international markets or binary type decisions (to replant or not to replant; to harvest or not to harvest). C-LCAs may be developed to illustrate different scenarios relative to a baseline, business-as-usual, or counterfactual reference case.

Figure 4 and the subsequent thought experiment described in Box 2 illustrate potential consequences of how an increase in bioenergy demand might be simulated using a consequential LCA model of the bioenergy system. The results of the C-LCA model indicate how a marginal change in demand will feed through to a marginal change in environmental impacts.

Figure 5. An illustration of the potential consequences of increased bioenergy demand to substitute natural gas (illustrative only).



Box 2. Consequential Thought Experiment: What are the consequences of an increase in biomass demand?

An increase in biomass demand to substitute natural gas as a fuel could have a number of consequential effects. The overall effect would be the sum of the additional emissions and removals. ***The considerations listed here are preliminary and meant to be illustrative, not definitive analyses:***

- The increase in demand might first be felt as competition for the current stock of harvested wood products:

- Low value material that would have previously gone to waste or decomposed in timber processing would be diverted to bioenergy, with a potential reduction in methane emissions[25];
- Some medium value materials that would previously have been used for short lived products such as packaging or medium life products such as pallets and fibre board may be diverted to bioenergy, raising the price of these materials (low impact on emissions, since most of this material would be oxidised within 1-5 years);
- The flow of materials to long-lived structural timber products is less affected unless the increase in bioenergy demand was extreme.

- If the increased demand was sustained the impact might then be felt as an increased demand for harvesting of timberland, with the following effects:

- Thinning or harvesting timing may be brought forward, reducing the rotation length of forest management, resulting in a lower than previous stock of carbon (reduction in forest carbon stock / net increase in emissions);
- In cases where forest stands are not being adequately thinned, thinning can have a positive impact on the quality and value of the final stand, which may lead to a higher proportion of end products going to long-lived timber products;
- Increased efforts to extract material from forest may result in practices such as stump extraction, associated with increased soil disturbance (increase in emissions from soil and deadwood pools);

- Sustained demand may also result in increased investment in forest creation for timber and by-products:

- Increase in forest planting or improved yields resulting from investment in superior growing stock (increase in carbon removal from the atmosphere, but possible increase in emission from soil disturbance, depending on where and how trees are established);
- Reduction in the conversion of existing woodlands to other land uses such as forage and cash crops;
- Increase in timber production may feed through to increase use of structural timber in the built environment and displacement of carbon intensive materials (net reduction of emissions).

- The reduction in consumption in natural gas could feed through to decisions regarding future investments in fossil fuel exploration and longer-term supply of natural gas:

- Potential reduction in emissions beyond the immediate substitution of NG resulting from reduced demand as investor capital flees fossil fuel exploration.

While proponents of consequential LCA have proposed that these types of analysis are suitable for many decision-making situations, including informing public consumption choices through food labelling, the author’s view is that consequential LCA is most appropriate and most useful as a guide to policy makers, to inform major decisions on climate and energy matters. The reason for this is the need to assemble expert knowledge and organise stakeholder discussions on the consequential impacts of policies and to incorporate these into C-LCA models. This means C-LCA studies need to be properly planned and resourced and set within a policy making framework.

[25] It has been observed that one of the first responses to markets for bioenergy is for sawmills to fit equipment to catch and pelletise sawdust and other fine materials.

An important aspect of organising C-LCAs in the forest and land use sector is the lack of reference data showing how a change in one variable (e.g. demand for a type of wood product) affects another variable (e.g. rate of harvesting), over what range and timeframe and subject to what conditions. Experiences of modelling land use change decisions resulting from demands in the agricultural sector have shown that there can be many complicating factors such as land tenure norms, legal issues, terms of trade and exchange rate fluctuations that make any results subject to wide ranges of uncertainty.

Box 3: Searchinger et al's consequential modelling of bioethanol demand
A controversial but influential paper by Searchinger and colleagues in 2008[26], proposed that subsidies for increasing the incorporation of bioethanol into gasoline in the US would lead to *indirect land use change* (ILUC) in Brazil and other Latin American countries even if the ethanol was produced in the US from US grown corn.

The paper modelled a series of market linkages showing how increased demand for corn, driven by the bioethanol subsidies, might crowd-out US soybeans from Midwest farms, leading to increased demand for soybeans from south America, where soybean expansion has long been associated with conversion of forest to agriculture along with its associated carbon emissions and biodiversity impacts.

Subsequent research questioned many of the Searchinger-team's assumptions and their main assertions were not borne out by the implementation of US and European biofuel policies. Nevertheless, ILUC remains an important topic of discussion and likely influence on future policy. Just because ILUC did not materialise at the scale anticipated in the original paper, it does not mean that it could not occur in the future, with a different set of market and regulatory conditions.

From an accounting perspective, a methodological flaw in the Searchinger et al approach was the comparison of bioenergy using consequential LCA models with emissions from fossil fuel gasoline accounted using an attributional accounting method.

[26]Timothy Searchinger; et al. (2008). "Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change". *Science*. **319** (5867): 1238–1240.

Attributional Life Cycle Assessment for Bioenergy

Within an attributional LCA, the observed GHG emissions within the supply chain scope are divided between the units of consumption or output on a normative or "fair share" basis.

The attributional approach is commonly used to describe emissions associated with the use of electricity, air travel, road transport, fuels and many other products and services. There are a number of embedded assumptions and conventions used within the attributionally derived emission factors[27]:

- Fair sharing of emissions across the end users: business class passengers are attributed a higher proportion of emissions associate with air travel than economy passengers. Emissions may also be assigned to components on a mass or volume balance basis.
- Simplification of system behaviour for practicality: while the emissions per unit of grid electricity vary seasonally and during the day, standard annual factors are generally accepted for a given national or regional grid. Attributional factors do not include market substitution effects that may occur when additional units of product are demanded or no longer required by the end consumer.
- Truncation of scope for ease of application: emission factors for power and fuels rarely include aspects such as upstream exploration and production, manufacture of capital equipment. Factors for aviation rarely include manufacture of the aircraft or production of the fuels (these are sometimes assumed to be *de minimus*).

The attributional approach is also the basis of organisational or corporate GHG accounting, which has become enshrined in corporate reporting standards for listed and large private companies – an organisation's "Scope 3" emissions are effectively the upstream and downstream emissions associated with the supply chain of an organisations goods or services.

Key assumptions within an attributional LCA determine the way in which emissions from a given process with multiple outputs or user types within a supply chain are split between the outputs – for example, the emissions of an aircraft between freight, business and economy passengers, the different components from a chemical separation process, the heat and power from a combined heat and power plant. These attribution rules may become more or less accepted or normalised within certain sectors – for example. The allocation of emissions may be based on the relative mass, energy content, proportional economic value or other attributes, but is essentially normative.

Within a bioenergy supply system an attributional LCA would estimate the emissions from each component of the supply chain from the forest through to the delivery of the energy and where applicable the sequestration or release of final CO_2 emissions.

Key assumptions would be made for attributing emissions or removals resulting from the forest production stage, as calculated from changes in the stock of carbon within the supply area to different forest products – timber, pulp and fuelwood. Another key assumption would be the area over which the supply area is determined for a sawmill or pulp mill this might be in the order of several millions of hectares of forest.

Attributional life cycle and organisation-level accounting provides a high degree of certainty of emissions per unit of output at a given point in time, in the sense that it is based on activity data from supply chains and operations combined with well understood emission factors. However, attributional assessments provide limited insights into potential systemic

[27] For a wide range of of global emission factors, their sources and assumptions visit emissionfactors.com

changes or counterfactual scenarios across an industry or at a national policy level.

Drax applies the attributional LCA approach to reporting the GHG emissions associated with its bioenergy supply chain[28], the main sources of emissions being the pelletising and sea transport stages of the chain.

3.3 Comparative Summary of Accounting Frameworks

In summary, the national GHG inventory should, in theory, capture all the resulting emissions and removals, including the substitution of fossil fuel - which is likely to have been the motivation for the policy in the first place. As GHG inventories are retrospective, they do not predict future emissions and as they are inventories the reports may not identify causes or effects of historic changes, although some countries do provide explanatory information on the drivers behind changes in national land use emissions and descriptions on how policies are expected to address emissions from different sectors, over time.

Consequential LCAs seek to assess impacts of changes to bioenergy demand on the energy system as a whole. Ideally this analysis would identify key thresholds or conditions that could be applied to limit negative impacts and enhance positives. It delivers the results as a marginal change in emissions per marginal unit of production.

An attributional LCA describes the emissions associated with the production of an average unit of bioenergy from the point of origin to its conversion to energy. In the case of forest products this should include any emissions associated with loss of carbon stocks from forests within the supply area. It would also include items such as transportation emissions that might be missed out of a C-LCA as not significant. Attributional LCAs are particularly useful for identifying the main sources of GHGs within a supply chain, for managing and reducing emissions within the supply chain and for comparing similar products – e.g. a food product produced locally v's one shipped in via air freight.

An attributional LCA reflects the average emissions per unit output of the production system at a point in time and not the marginal impacts of changes in demand or new technology at the system level.

[28]https://www.drax.com/sustainability/sourcing-sustainable-biomass/#ensuring-sustainable-biomass

Table 2. Summary of carbon accounting approaches and their suitable applications

National Inventory	Consequential	Attributional
Gives a complete, consistent annual report of anthropogenic GHG emissions. **Does** give a large-scale picture of emissions and how they have changed over time; **Does not** show the impact of a particular activity or technology, or project forward in time. Does not associate emissions with units of production (in case of harvested wood products). **Useful for** tracking national efforts to manage and reduce GHG emissions.	Estimates impacts of new technologies, policies, demands. **Does** give a picture how emissions may change, albeit simulated; **Does not** quantify actual emissions associated with a specific unit of production. **Useful for** assessing the impacts of policy changes and technology shifts.	Divides observed emissions between users of a service or product. **Does** consistently account for observed emissions in a simple, direct way; **Does not** show the impact of a change in demand or new technology at the systemic level. **Useful for** identifying main sources of emissions within a supply chain, potential improvements within a supply chain, comparing similar products.

4. Applications of Carbon Accounting Frameworks

4.1 Forest sources and sinks under the Kyoto Protocol and Paris Agreement

Emissions from and removals by forests were an important but contentious component of the Kyoto Protocol (KP), which was agreed in 1998, and operated from 2005 -2020, - the first set of legally binding commitments for governments negotiated under the UNFCCC.

Under the KP, which set binding targets for the industrialized countries, removals of carbon from the atmosphere by afforestation, reforestation and a limited set of activities in managed forests could count towards the national targets. National emissions included those from land use and land use change. A major area of contention was the degree to which carbon removals from the atmosphere by managed forests could contribute to national targets. One of the reasons given for the US pulling out of Kyoto was the limited role allowed for forest carbon uptake, noting the strength of US forest removals during this time.

The treatment of bioenergy within the KP was based on national greenhouse gas inventories, with the emissions of biomass covered by changes in stocks of carbon within the land use sector and pools of harvested wood products.

In 2009, Searchinger's research group at Princeton University along with Kammen and colleagues at the University of California asserted that treating biomass carbon as "effectively neutral", relative to fossil fuels, could lead to the substitution of coal by biomass at a massive scale: *applying this incentive globally could lead to the loss of most of the world's natural forests as carbon caps tighten*[29].

The authors also made the distinction between crops grown specifically for the purpose of bioenergy production, which could be counted as carbon neutral, versus those that were not, which should be treated as emissions. They proposed a scheme to credit "additional" sources of bioenergy as opposed to those that were for other purposes. Searchinger and Kammen's proposed changes to carbon accounting for biomass were rejected by the IPCC yet the outcomes predicted by their consequential assessment were not realised. The predictive failure of these models may have been partly attributable to sustainability safeguards preventing the importation of biomass associated with deforestation and degradation but could also have occurred because emissions trading schemes never delivered carbon prices at the levels the authors had predicted. Thus, energy buyers could rarely exceed the price of mainstream timber products. At the same time other forms of renewable energy such as wind and solar became more competitive, with the result that biomass made a modest contribution to the replacement of coal fired generation capacity. Finally, land managers in Europe responded to market demands by planting more forests[30], and in the USA the stock of growing timber increased[31]. The extent to which these observed increases in forest resources were achieved in spite of or because of climate policies is still uncertain, since the growth in production forest planting in Europe was also favoured by tax incentives and changes to agricultural support.

The Paris Agreement, which was adopted in 2015, and includes most developing as well as industrialized countries, takes a more holistic view of the land use sector and addresses areas such as emissions from deforestation and forest degradation. Countries are required

[29]https://www.sciencedaily.com/releases/2009/10/091022141126.htm

[30]Forest area in the EU increased by 10% from 1990 to 2020 and forest growing stock by over 40% (Eurostat)

[31]The growth-to-removals ratio at the US National scale was 1.92; i.e., growth was nearly twice the volume removed from timberland.

to produce a series of plans and reviews on a 5 yearly cycle to determine their needs and assess their performance, with the overall aim of halving greenhouse gas emissions by 2050, relative to 1990 levels.

Carbon accounting frameworks established for Kyoto are taken forward with increased options to reflect the diverse situations of different countries. Many countries, the EU and UK included, are developing Forest Reference Levels (FRLs) that will relate the ongoing reporting of emissions and removals by Land Use, Land Use Change and Forestry relative to reference periods reflecting historic forest management. In the case of the EU the FRL period is from 2000–2009. The use of historic reference periods is intended to reduce the ability for countries to inflate the climate mitigation attributed to the forest sector (including bioenergy) relative to counterfactual scenarios based on policy assumptions[32].

4.2 Accounting for forest biomass in the EU Renewable Energy Directive

The 2009 EU Renewable Energy Directive (RED) mandated member countries to achieve an aggregate 20% renewable energy consumption by 2020 to support the EU's Kyoto Protocol commitments on greenhouse gases. The target had been agreed in 2007 when renewable energy comprised around 8.5% of gross final energy consumption across Europe.

Despite the rapid growth of wind and solar for power generation, biomass, mainly in the form of woodfuel, represents almost 60% over gross energy use within the EU (excluding transport) because of its widespread use for heating. Over 95% of the EU's woodfuel is domestically produced[33].

While the 2009 RED introduced somewhat stringent sustainability requirements for liquid biofuels used for transport, the environmental protections on sources of woody biomass were more limited and have been strengthened in RED II (2018/2001).

Under RED II, bioenergy must be produced from feedstocks complying with specific sustainability and greenhouse gas (GHG) emissions saving criteria. Only the bioenergy fulfilling these criteria may contribute towards the climate and renewable targets of countries and be eligible for financial support.

The RED II sustainability sourcing criteria for forest biomass users apply to facilities of >20 MW capacity and are as follows:

1. Art. 29(3), Art. 29(4) and Art. 29(5) -> No-go areas are defined for agricultural feedstocks, in which production for bioenergy is not allowed from land that was classified, in or after 2008, as primary forest, highly biodiverse forests, areas designated for nature protection purposes (including threatened or endangered ecosystems or species), highly biodiverse grasslands (natural or semi-natural) or land with high carbon stocks, including wetlands, forested areas and peatland.

2. Art. 29(6) -> the country in which forest biomass was harvested has national or subnational laws applicable in the area of harvest as well as monitoring and enforcement systems in place ensuring: i. the legality of harvesting operations; ii. forest regeneration of harvested areas; iii. that areas designated by international or national law or by the relevant competent authority for nature protection purposes, including in wetlands and peatlands, are protected; iv. that harvesting is carried out considering maintenance of soil quality and biodiversity with the aim of minimising negative impacts; and v. that harvesting maintains or improves the long-term production capacity of the forest.

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[32] Camia, A., Giuntoli, J., Jonsson, K., Robert, N., Cazzaniga, N., Jasinevičius, G., Avitabile, V., Grassi, G., Barredo Cano, J.I. and Mubareka, S., The use of woody biomass for energy production in the EU, EUR 30548 EN, Publications Office of the European Union, Luxembourg, 2020.

[33] Scarlat, N., Dallemand, J., Taylor, N. and Banja, M., Brief on biomass for energy in the European Union, Sanchez Lopez, J. and Avraamides, M. editor(s), Publications Office of the European Union, Luxembourg, 2019,

3. Art. 29(7) -> Provisions for carbon accounting linking the EU REDII with the land use, land-use change and forestry (LULUCF) sector. Specifically, the country in which the forest biomass is produced shall meet the following LULUCF criteria:

- *i. the country is a Party to the Paris Agreement;*
- *ii. it has submitted a Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC), covering emissions and removals from LULUCF which ensures that either changes in carbon stock associated with biomass harvest are accounted towards the country's NDC (this is the case of EU countries, which shall follow the provisions of LULUCF regulation 2018/841), or there are national or sub-national laws in place, applicable in the area of harvest, to conserve and enhance carbon stocks and sinks, and providing evidence that reported LULUCF emissions do not exceed removals;*
- *iii. in cases where the above criteria are not fulfilled, then management systems must be in place at forest sourcing area level to ensure that carbon stocks and sinks levels in the forest are maintained, or strengthened over the long term.*

In addition, large biomass users are required to conduct a truncated LCA analysis of their supply chain to demonstrate that it meets a basic level of efficiency. A greenhouse gas saving of at least 70 % is required for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80 % for installations starting operation from 1 January 2026.

The LCA approach proposed is an attributional model and at present excludes changes in carbon stocks from supply catchments. The approach is intended to promote efficient bioenergy pathways. However, the lack of connection with land use policies is a potential gap that could be addressed in future.

Biomass that does not meet the above requirements is effectively considered non-compliant and treated as a fossil fuel.

4.3 Accounting for forest biomass in the EU Emissions Trading Scheme

The EU Emissions Trading Scheme (EUETS) sets a cap on the GHG emissions that can be produced from major point sources of combustion within the EU, such as power plants, cement factories and steel foundries. Emission allowances are issued to regulated entities in a part allocated and part auctioned system. The total number of allowances issued into the scheme is reduced year on year, participants are allowed to trade allowances and this scarcity creates a price of allowances to incentivize emission reductions, through switching to lower carbon energy sources. The UK has left the EUETS following Brexit and is in the process of setting up an equivalent scheme.

Under the EUETS plants using bioenergy are able to count this as a zero emissions fuel provided it meets sustainability criteria that are aligned with the Renewable Energy Directive[34] . However, implementation of sustainability criteria within the EUETS appears to be lagging behind the RED II criteria[35].

4.4 Accounting for forest biomass under the UK Renewables Obligation

The Renewables Obligation (RO) is one of the main support mechanisms for large-scale renewable electricity generation in the UK.

The RO came into effect in 2002 in England and Wales, and Scotland, followed by Northern Ireland in 2005. It places an obligation on UK electricity suppliers to source an increasing proportion of the electricity they supply from renewable sources. The RO closed to all new generating capacity in 2017.

ROCs are certificates issued to operators of accredited renewable generating stations for the

[34] European Commission 2017. Biomass issues in the EU ETS. Guidance Document (link)

[35] https://ec.europa.eu/energy/topics/renewable-energy/biomass_en?redir=1

eligible renewable electricity they generate. Operators can trade ROCs with other parties. ROCs are ultimately used by suppliers to demonstrate that they have met their obligation.

Electricity from sustainable biomass is one of the forms of generation eligible under the scheme. Rather than accounting for carbon emissions and removals the scheme sets a number of criteria that must be fulfilled to demonstrate that the biomass is from both legal and sustainable sources [36]. These requirements are closely aligned with the Forests Europe[37] sustainable forest management criteria to ensure that the biomass used for ROCs do not contribute to deforestation or forest degradation.

These criteria cover aspects including the avoidance of harm to ecosystems, the maintenance of productivity, the use of pesticides, consideration of biodiversity and social welfare of workers and forest stakeholders.

Forests under various national and international accreditation schemes such as the Forest Stewardship Council (FSC), and the Programme for the Endorsement of Forest Certification (PEFC) were recognised as meeting the sustainability evidence requirements. The Sustainable Biomass Partnership (SBP) and several other schemes have been benchmarked against the evidence requirements[38].

In addition to providing evidence of sustainable sourcing, generators using non-waste bio-materials at a scale greater than 1MW[39] are required to produce monthly and annual reports on the carbon intensity of the fuel using a truncated attribution LCA method to show that the processing meets a base level of efficiency (bioenergy installations are required to meet a GHG threshold of 55.6g CO_2eq/MJ of electricity, declining to 50g CO_2eq/MJ in 2025). This truncated LCA does not take into account changes in the forest carbon stock within catchment areas but assumes that these are not declining because of the sustainability certification criteria mentioned above.

The main way in which greenhouse gas emission reductions are meant to be ensured through this scheme is through the increased stringency of sustainability criteria.

4.5 Corporate GHG Accounting

An increasing number of businesses (including Drax) are now required to report emissions of carbon from their operations under financial disclosures relating to climate change. In the UK emissions reporting is mandatory for all listed companies and a streamlined version of this requirement will be extended to large private companies later this year[40].

The carbon accounting methods used for corporate GHG accounting have been developed by a consortium of interested parties led by WBSCD and WRI, known as the GHG Protocol[41]. The approach follows a combination of inventory and attributional methods, with activities grouped into Scopes: Scope 1 are direct emissions from fuel combustion and other fugitive emissions from company sites; Scope 2 covers the fuel combustion emissions associated with electricity and heat consumed by the organisation, and Scope 3 can include many offsite emissions within the supply chain from business travel through to the emissions associated with the inward transportation and outsourced manufacturing.

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[36] Woodfuel Advice Note, 2017 (link)

[37] https://foresteurope.org/sfm-criteria-indicators/

[38] Renewables Obligation Sustainability Criteria. 2018. Ofgem (link)

[39] https://www.ofgem.gov.uk/system/files/docs/2018/04/ro_sustainability_criteria.pdf

[40] https://www.gov.uk/guidance/measuring-and-reporting-environmental-impacts-guidance-for-businesses

[41] https://ghgprotocol.org/corporate-standard

Bioenergy use within the corporate GHG accounting framework is modelled on national accounting procedures. The CO_2 emission is accounted for as zero within the inventory of the businesses but is also reported as an emission to the atmosphere outside of the Scopes for information purposes. Carbon fluxes within the land sector are not yet covered. However, the GHG Protocol is currently revising its standards to take better account of emissions and removals from agriculture, forestry and land use.

4.6 Certification Schemes and Industry Developments

Some cross-sector schemes and leading bioenergy industry players have sought to develop processes that go beyond compliance requirements to provide efficient solutions for assurance on sourcing.

The Sustainable Biomass Programme (SBP), a sector-wide certification body whose purpose is to facilitate the economically, environmentally and socially responsible use of biomass enabling climate goals to be met. The SBP's certification system builds extensively on the pre-existing Forest Stewardship Certification (FSC) and Programme for the Endorsement of Forest Certification(PEFC) schemes to draw together a coherent assurance process for sustainability assessment in the bioenergy sector.

There are six SBP Standards, which collectively represent the SBP certification framework, or scheme, against which organisations can be assessed for compliance by independent third-party Certification Bodies (CBs).

SBP's Standard on Feedstock Compliance includes specific criteria relating to the maintenance of forest carbon stocks. While there is no specific requirement to monitor carbon stocks there are protections for high carbon stock land, including wetlands, and peat and carbon stocks are protected, with a note - *where there is a direct land use change, the carbon emissions associated with this may need to be calculated* [42]. The SBP appears to take an attributional approach to supply chain GHG accounting as it only makes reference to Direct (as opposed to indirect) land use change.

ENPlus, a certification standard specifically for wood pellets, includes a requirement to conduct a GHG calculation on a per tonne of pellets basis. However, the scope of the calculation only covers processing and logistics, with no emissions or removals at the forest level[43].

In addition to cross-industry groups, some industry players are also developing their own internal procedures to assure or protect the carbon benefits of forest biomass. An important development by Drax Plc has been the adoption of sustainable biomass sourcing criteria to maximise carbon benefits (Box 4).

[42] Sustainable Biomass Programme Standard 1, Criterion 2.9 (link)

[43] ENPlus (link)

Box 4. Drax's Approach to Maximising carbon benefits, based on criteria proposed by Matthew's et al (2018)[44]

Using:
- Responsibly sourced sawmill residues.
- Forest residues from regions with high rates of decay, or where this material is extracted to the roadside as part of standard harvesting practice.
- Thinnings that improve the growth, quality or biodiversity value of forests.

Only using roundwood that:
- Helps to maintain or improve the growing stock, growth rate and productivity of forests.
- Helps to improve the health and quality of forests, for example by using storm, pest or fire damaged wood.
- Is not merchantable for use as saw-timber products.

Not using:
- Biomass that drives harvesting decisions that would adversely affect the long-term potential of forests to store and sequester carbon.
- Biomass that increases harvesting above the sustainable capacity of forests.
- Biomass that displaces solid wood product markets.
- Biomass that comes from stumps.

The above criteria are particularly useful because they provide the basis for operational measures that can be objectively verified that link directly to key assumptions within both attributional and consequential LCA frameworks.

Drax has also initiated the development and publishing of catchment level reports for its main sourcing regions[45]. These initial reports provide a useful picture of how biomass sourcing is affecting the overall growing stock of forests within the supply regions.

Further investment in systematic data capture will be required in many regions to provide the level of evidence needed to provide strong assurance on the effectiveness of these criteria.

[44] https://www.drax.com/wp-content/uploads/2019/10/CIB-Summary-report-for-ECF-v10.5-May-20181.pdf

[45] https://www.drax.com/sustainability/catchment-area-analyses/#reports-and-summaries

5. Recommendations for Addressing the Carbon Challenges in Bioenergy

The use of wood for bioenergy is likely to remain a component of forest economics and forest management into the future - there will always be a proportion of harvested biomass that is not suitable for conversion to material products and energy extraction is a better option than allowing this material to decompose, biomass extraction can also be an important part of forest restructuring to develop more diverse and productive forest estates. The following table sets out preliminary recommendations arising from this study for aspects of carbon management and reporting that could be improved within the bioenergy industry.

Areas for Consideration	Possible Actions
Conserving and Increasing Forest Carbon Pools • Sourcing from well managed forest regions (sub-national areas) and estates; • Ensure forest carbon stocks are stable or increasing at the supply catchment area level.	• Support land use policies and forest codes that promote carbon management at the regional and forest estate level; • Promote soil carbon conserving measures (avoid stump removal and deep tillage and drainage on organic soils); • Promote improvements to the monitoring of forest biomass; • Continue to use and monitor the effects of Matthews' et al. Criteria (Box 4); • Mapping and public communication of what forest types are suitable for different types of product extraction.
Conserving and Increasing Long-Lived Harvested Products Carbon Pools • Build positive interactions with other forest stakeholders (forest product industries, investors and the public);	• Monitor proportion of HWPs going to bioenergy and consider price thresholds at which diversion from long-lived pools could occur;; • Monitor impacts on pulpwood and other producers and communicate to reduce negative competition; • Collaborate on integrated carbon accounting for HWPs to ensure a consistent framework for the industry, avoiding gaps or double-counting; • Continue to use and monitor the effects of Matthews' et al. criteria.
Broader Sustainability • Support the conservation of natural forest through biodiversity protection measures • Support sustainable livelihoods linked to forest management and products	• Develop and communicate clear guidelines for the circumstances, methods and extent to which biomass may be extracted from natural forests of various types (e.g. for fire management or pest control) • Develop public understanding of the role of bioenergy as part of broader forest management • Monitor impacts of bioenergy demand on natural forests and communities

Legitimate concerns will be raised where bioenergy demand distorts existing markets for harvested products or affects the way forests are managed, especially if this leads to decisions that are not optimal from a long-term carbon management perspective, such as premature felling, stump removal or the diversion of material from long-lived products.

To address potential carbon management and related sustainability concerns the bioenergy industry should seek long-term alignment and engagement with other forest and land users, including the public, for whom forest management is about much more than carbon. The way to approach this is by understanding the appropriate role and potential for bioenergy output at a forest, landscape and regional perspective, over the long term. The development of consequential analyses of a range of bioenergy options could support this if it was undertaken in a way that involved the full range of forest stakeholders.

There remains a gap in policies for optimising the management of forests and use of forest products for climate change mitigation in the area of incentives for promoting carbon storage in long-lived timber products. At present there is an uneven playing field, insofar as renewable energy incentives create a risk of pulling material towards the energy sector. While the gap between sawlog prices and woodfuel prices is usually sufficient to maintain an economic preference towards the longer-lived products, a potential tightening of carbon markets has the potential to undo this and should be closely monitored.

Biomass certification schemes, such as the Sustainable Biomass Programme (SBP), can play an important role in levelling-up the standards to which biomass industries operate and could contribute to the good management of forests. However, it should be recognised that standardisation and certification systems alone do not address many of the broader interests around forests, which are and should remain multipurpose resources, whether they are even-aged plantations or more diverse natural woodlands.

For the watchers and critics of bioenergy industries and forestry businesses, the development and application of land use policies, sustainability criteria and monitoring at the forest and landscape level appears to be a more fruitful approach than trying to reset carbon accounting methods and conventions that have been adopted and applied internationally for over 25 years.

At the global level, it is important to recognise that while deforestation and forest degradation continue to be major problems in the tropics there will always be potential for a linkage to be drawn between the use of forest products in western countries and the pressures on forests in developing countries, even if the majority of land use changes are related to demand for agricultural land. It is therefore prudent for forest industries in Europe and North America to support efforts to improve forest management and conservation throughout the world.

Regarding the issue of the accounting of woodfuel and other biogenic materials as zero-carbon fuels in various renewable energy policies and emissions trading schemes, the best way forward would be to build upon existing UN and IPCCC approved methods for forests and harvested products rather than reinvent differentiated accounting frameworks for forest biomass.

Specifically, with improved data from the supply areas for pellets and other fuelwood products, it should be possible to provide inputs to attributional LCA's on the emissions and removals at the forest catchment level and for these to be allocated, through sector and industry agreed attribution norms to the forest products, including those used for energy.

By using a combination of consequential LCA for policy analysis, attributional LCAs for supply chain and sector reporting and organisational GHG reporting for entity level reporting it should be possible to achieve alignment and consistency of carbon accounts across the forest and forest products system as a whole.


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