Raising the Standard for Assessing the *Environmental Benefit* of Bioenergy

Integrity of the emission reduction benefits of Peak Carbon's investments is fundamental to our objectives. The following paper outlines Peak Carbon's principles on bioenergy from a sustainability perspective and why we strive to, as a minimum, use these calculations principles to assess if our investments are meeting the objectives of the Paris Agreement in having a net positive impact on reducing emissions, even if the regulatory regime they are governed by has a less onerous approach.

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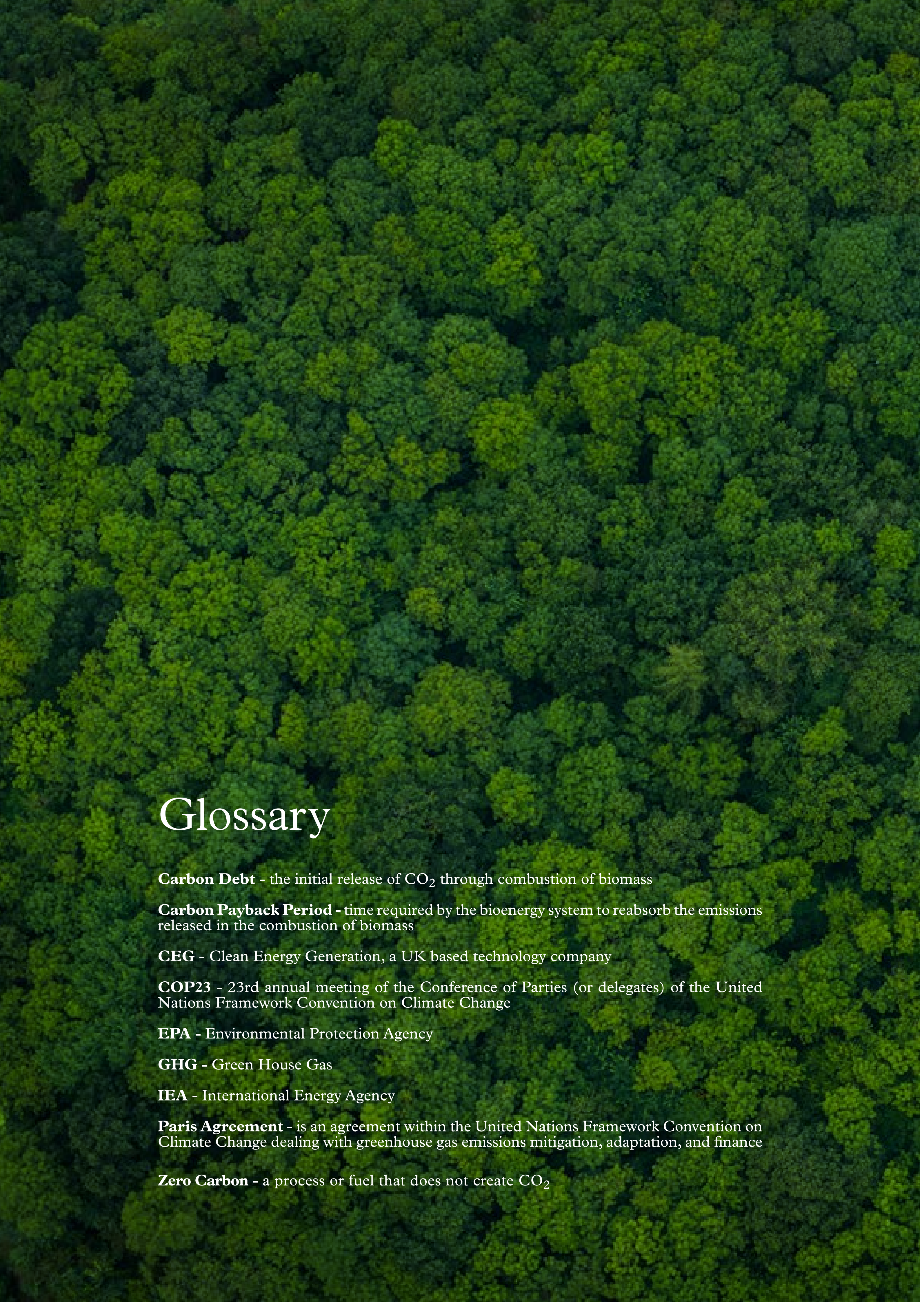

Glossary

Carbon Debt - the initial release of CO_2 through combustion of biomass

Carbon Payback Period - time required by the bioenergy system to reabsorb the emissions released in the combustion of biomass

CEG - Clean Energy Generation, a UK based technology company

COP23 - 23rd annual meeting of the Conference of Parties (or delegates) of the United Nations Framework Convention on Climate Change

EPA - Environmental Protection Agency

GHG - Green House Gas

IEA - International Energy Agency

Paris Agreement - is an agreement within the United Nations Framework Convention on Climate Change dealing with greenhouse gas emissions mitigation, adaptation, and finance

Zero Carbon - a process or fuel that does not create CO_2

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About the author

Created in 2018 when top executives, independently benchmarked as the market leader in environmental commodities, left fossil fuel energy companies to set up their own firm in pursuit of their ambition to accelerate positive environmental impact in the low carbon and clean energy sector. Peak Carbon's goal is simple, to combine sector leading experience with proven analytical tools and techniques to deliver large scale investment opportunities with a positive environmental impact focus without sacrificing total return. Capitalizing on over a combined 50 years of proven investment success, building biofuel value chains and operating in global energy commodity markets, Peak Carbon has built a team of experts across the whole bioenergy value chain - from biomass growth and handling & logistics to bioenergy upgrading and engineering and finally distribution and utilisation. Peak Carbon Capital's goal is simple, to consistently

About this document

This paper sets out Peak Carbon's Sustainable Bioenergy Approach - our methodology to ensure that the sustainability of biofuels generated through our investments stands up to detailed scientific scrutiny. Our belief is that regulation will continually be updated to reflect growing scientific understanding of bioenergy life cycle analysis and will eliminate biofuels generated from unsustainable practices, like clear cutting of trees. Through adopting this Sustainable Bioenergy Approach, at times above and beyond the status quo of regulatory frameworks, Peak Carbon believe we can ensure robust positive environmental impact investments and be part of best practice benchmarks in the bioenergy industry.

Contact: info@peakcarboncapital.com

Published January 2019.

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Background: Biomass and Carbon Neutrality

At the global climate summit (COP23) in 2017 a 20-country alliance known as the 'biofuture platform' announced a series of collective goals aimed at increasing the share of bioenergy in energy use[1]. According to the IEA's 2C energy forecast scenario, by 2060 bioenergy will make up 17% of final energy consumption compared with 4.5% today[2].

In 2009 the European Union ruled that emissions associated with the combustion of biomass for energy purposes should be counted as zero[3]. Other regulatory instruments across the world have followed a similar path; in April 2018 the US Environmental Protection Agency released a statement of policy noting:

"EPA's policy in forthcoming regulatory actions will be to treat biogenic CO_2 emissions resulting from the combustion of biomass from managed forests at stationary sources for energy production as carbon neutral." (EPA, 2018[4])

This approach is founded upon the view that as new biomass grows over time to replace that used for energy production, the reabsorption of CO_2 via photosynthesis is able to offset the initial release of CO_2 on combustion (known as the 'carbon debt'). As long as forest biomass stock does not fall over time, absorption over time means there should be net zero emissions associated with biomass use. In the EU and other jurisdictions, whilst the biomass itself is considered carbon neutral, regulations do however account for the CO_2 associated with the supply chain for wood up to the point of combustion.

Under such an approach, analyses have shown that the greenhouse gas intensity of UK electricity generated using wood pellets originating in North America was 50-85% lower than that of coal based electricity[5,6]. The production of pellets for heat and electricity generation has risen from 14.3 million tonnes (Mt) in 2010 to 26Mt in 2015, 7.4Mt of which originated in the US and 1.6Mt in Canada[7]. However, recently published research shows the assumption of biomass to be zero carbon at source is too simplistic[8,9]. Beyond just accounting for supply chain emissions, sustainable emissions reductions requires accounting for the dynamics of forest regrowth and the timing gap between the emissions from combustion of wood products and later sequestration of CO_2 from subsequent regrowth. A 2012 EPA Science Advisory Board (SAB) peer review of the biogenic emissions accounting framework commented that:

"Carbon neutrality cannot be assumed for all biomass energy a priori. There are circumstances in which biomass is grown, harvested and combusted in a carbon neutral fashion but carbon neutrality is not an appropriate a priori assumption; it is a conclusion that should be reached only after considering a particular feedstock's production and consumption cycle."
(EPA, 2012[10])

Whilst existing bioenergy industry practices are compliant with regulatory guidance in regions - such as the EU, Japan and South Korea - Peak Carbon believe that, with more detailed scientific scrutiny, regulators will seek to increasingly limit the use of certain biomass types and require more comprehensive carbon lifecycle accounting to the extent that many present day bioenergy practices will be ruled out as a source of renewable energy as they do not create a net CO2 reduction. Peak Carbon therefore exclusively targets sources of bioenergy that are robust to examination of the supply chain emissions and the dynamics and timing of the associated forest stand.

1 http://biofutureplatform.org/statements/

2 https://webstore.iea.org/technology-roadmap-delivering-sustainable-bioenergy

3 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

4 https://www.epa.gov/sites/production/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf

5 http://iopscience.iop.org/article/10.1088/1748-9326/10/11/114019

6 http://iopscience.iop.org/article/10.1088/1748-9326/9/2/024007/meta

7 http://www.ieabioenergy.com/wp-content/uploads/2017/11/Two-page-summary-–-Global-Wood-Pellet-Industry-and-Trade-Study-2017.pdf

8 http://publications.jrc.ec.europa.eu/repository/bitstream/JRC70663/eur25354en_online.pdf

9 http://iopscience.iop.org/1748-9326/13/1/015007/media/ERL_13_1_015007_suppdata.pdf

10 https://tinyurl.com/y9bvcm3b

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The Peak Carbon Sustainable Bioenergy Approach

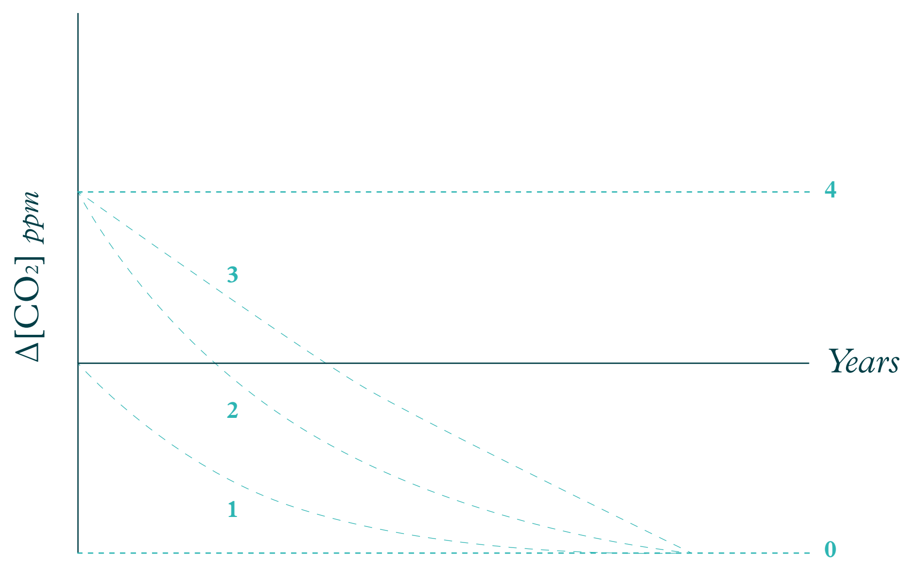
The Peak Carbon Sustainable Bioenergy Approach utilizes recommendations from the scientific community for a robust set of guidelines to ensure sustainable production and use of biomass. Through the innovative combination of biomass sourcing for energy and carbon offset projects, Peak Carbon will produce an industry leading, quantifiable, auditable approach to developing sustainable supply chains for bioenergy pathways.

Auditable Life Cycle Assessment within Feedstock Supply Chains

Case specific factors such as intensity of cultivation, transport and energy intensity of the conversion technology will all impact the emissions associated with the use of biomass.

Such impacts have been studied using the approach of 'carbon payback periods' that measure time required by the bioenergy system to reabsorb the emissions released in the combustion of biomass. The aim for a bioenergy system should be to ensure sufficient CO_2 is reabsorbed to ensure lower total emissions than the incumbent fossil fuels they aim to displace.[11]

Agostini et al. (2014) performed a literature review of carbon payback periods for various woody biomass to energy pathways can vary from as low as 3 to over 100 years.



0: 100% renewable (zero carbon) energy.

1: Bioenergy assumed to have the same combustion and processing efficiency as coal, and the same supply chain emissions; with 25% of biomass removed from the land harvested through thinning.

2: Actual efficiencies and supply chain emissions for wood pellets; 25% of biomass harvested through thinning.

3: As 3 but with 95% of biomass harvested (clear cut).

4: Clear cut with no regrowth of harvested land.

Fig.1: Change in atmospheric CO_2 concentration resulting from displacement of coal by wood.
$\Delta[CO_2]$ is the change in CO_2 concentration (ppm) in the atmosphere resulting from a single 1 EJ pulse of end-use energy from biomass relative to continued coal use. The bioenergy pulse causes an immediate increase in CO_2 concentration (the initial carbon debt) in scenarios 2–4 due to lower combustion and processing efficiencies for wood compared to coal. The year in which $\Delta[CO_2]$ falls below zero is the carbon payback period to reach fossil fuel parity. Over time biomass growth is sufficient to tend towards parity with 100% renewable (zero carbon) energy.

11 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/carbon-accounting-forest-bioenergy-conclusions-and-recommendations-critical-literature

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Quantifying the payback period requires accounting for both supply chain emissions and the emissions associated with combustion of the fuel (combined termed the 'carbon debt'). It is not uncommon for the supply chain emissions and combustion efficiency of biofuel to be worse than those of the fossil fuels they aim to displace. A recent report by Sterman et al (2018) highlights that for the replacement of coal with biomass, the lower energy density of biomass means initially more CO_2 is produced per unit of energy than using coal[12]. For different technologies, CO_2 produced per unit of energy can vary greatly, for example combustion efficiency of burning wet wood can be as low as 14% compared to >40% when directly replacing fossil coal with biocoal in an existing coal boiler/power plant. It is therefore critical to understand the carbon lifecycle of the specific feedstocks used in the biomass supply chain and in the context of the specific technology application, in order to determine as to whether the bioenergy is indeed a) carbon neutral, b) in fact more harmful in terms of emissions than the incumbent fossil fuel or more realistically c) somewhere in between. Using a data-driven approach, Peak Carbon accurately quantifies and makes decisions on technology, feedstock and supply chain that subsequently minimizes this payback period. At a minimum, Peak Carbon will ensure the carbon payback associated with investments, and the associated feedstock, exceed parity with the incumbent fossil fuel energy source it seeks to replace.

Peak Carbon's approach to sustainability therefore requires ensuring the reference fossil fuel parity level is accurately quantified. As a case study, CEG's torrefied biocoal is calculated to produce a carbon debt per MWh energy produced of 0.11t CO_2 greater than the coal it aims to displace due to the higher supply chain emissions of the torrefaction process relative to the coal value chain. Unlike white pellets, the combustion emissions of biocoal and fossil coal per MWh energy produced is considered to be at parity owing to CEG being able to produce biocoal with the same GJ/tonne net calrofic value as fossil coal and its biocoal's ability to displace fossil coal in existing power-plants and/or boilers without modifications[13].

Once the carbon debt of the biofuel value chain is determined relative to the to-be displaced fossil fuel value chain, then the nature of the feedstock, the forest management approach and the associated timeline for carbon sequestration is required to calculate the carbon payback period.

12 http://iopscience.iop.org/article/10.1088/1748-9326/aaa512/meta

13 High-Level Carbon Balance of Torrefaction, Report #2, Environmental Commodities Corp (2018)

The Peak Carbon Sustainable Bioenergy Approach

Peak carbon will only access sustainable woody feedstocks, namely from thinning, residues and diseased trees in diverse geographies which have no clear use in a counterfactual scenario.

A) Thinnings

Recent criticisms of bioenergy have highlighted concerns over the clearcutting of forest stands for biomass[14]. Clearcutting of sites is usually reserved for extracting high-value timber used in construction industries, whilst pulpwood, used in the bioenergy and pulp/paper industries, is extracted during silvacultural treatments such as thinning which aim to increase the yield of timber-quality wood[15]. Theoretically the price differential between pulpwood and timber should seldom see clearcuts used to supply bioenergy, however programs such as the Sustainable Biomass Partnership (SBP) do not ban the use of biomass sourced via clearcuts. Increasing demand for pulpwood for pulp/paper and bioenergy purposes has seen some intensely managed pine plantations used to grow pulpwood specifically for bioenergy use, with clearcut methodologies sometimes used in the harvest of these sites[16].

Sterman et al. report model results that show thinning of stands versus clearcut can reduce the carbon payback period to fossil parity by up to 28% in forest stands. It's this portion of forest fiber extraction which many see as the key wood feedstock for sustainable bioenergy:

"The emissions increase of the forest bioenergy systems are more limited in size and/or duration with forest residues, thinnings and salvage logging". (Agostini et al. 2014[17])

The sustainable use of thinnings requires ensuring that in the absence of use for bioenergy, the alternative use for the biomass (termed the 'counterfactual' scenario), would not cause lower total emissions. Diverting the wood from timber markets for example, where the carbon would be tied up for a longer period of time, would not be a sustainable use of resources. Alternatively, in some forest management regimes, 'precommercial' thinnings have limited value and are normally burnt or left to

14 https://www.dogwoodalliance.org/wp-content/uploads/2017/06/Sustainable-Biomass-Program-Report.pdf

15 http://extension.umd.edu/sites/extension.umd.edu/files/_docs/programs/woodland-steward/EB-407_ForestThinning.pdf

16 https://www.energy.gov/eere/bioenergy/2016-billion-ton-report

17 https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/carbon-accounting-forest-bioenergy-conclusions-and-recommendations-critical-literature

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rot in situ, producing methane which is over 24 times as potent a GHG as carbon dioxide. In such a situation the avoided emissions need to be subtracted from the initial carbon debt, lowering payback periods.

Given the payback periods of a specific bioenergy pathway, it's essential that the management and rotation cycle of a tract of forest optimizes the time to fossil fuel parity and then creates further sequestration to ensure overall emissions reductions versus fossil fuel use. Although the US South East pine plantations have played host to most biomass pellet production for export to Europe, Peak Carbon's joint carbon offset project and bioenergy feedstock production will target geographies with forests managed on longer rotation cycles.

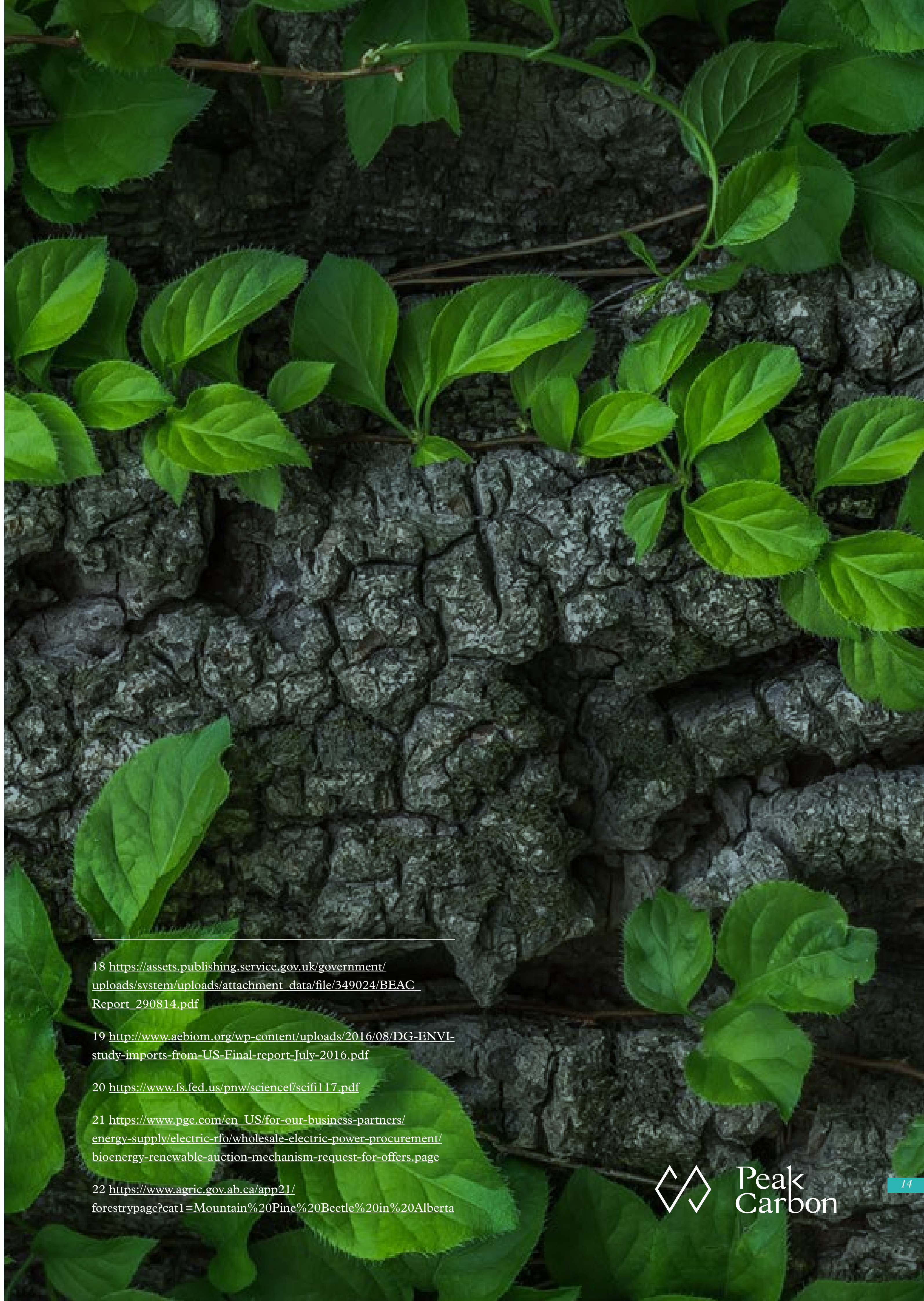
Whilst the modeling of biomass payback periods show paybacks for a range of situations, accurate assessment requires case specific approaches, mirroring the variation in forest management practices between timberlands. Hardwood stands in the North East US, for example, typically have rotation cycles closer to 80 years with harvests mostly via thinning, even for merchantable timber. Most models also center on the use of wood pellets for power and heat, but further work needs to be performed into newer pathways such as woody biomass to biojet and other fuels. Peak Carbon will utilize these dynamic modeling approaches, recognizing the constant development of scientific efforts, when valuing the sustainability of bioenergy investment opportunities.

B) Residuals

Alongside thinnings, 'residuals' are often identified as a low-carbon woody biomass feedstock. The term covers both the by-products of the timber/paper mill operations and the non-merchantable biomass left over during the felling of trees for timber/pulpwood purposes. In both instances the counterfactual use of burning the residuals or leaving them to rot in situ makes them ideal for use in bioenergy[18]. Currently, most logging residuals are poorly suited to use for white pellets for power generation due to a high ash content[19]. Through working with technologies such as torrefaction Peak Carbon aim to make use of a wider pool of residuals than existing bioenergy pathways, reducing the emissions currently associated with the burning/rotting of such biomass.

C) Diseased and fire hazard wood

Overstocking of forestland can leave it prone to disease and wildfire[20]. As a recent communication from the EPA noted, the removal of dead/diseased trees can help both improve forest health and also provide a sustainable fuel. Such an approach has already been taken in California where in response to rampant forest fires, the state legislature introduced a carve out in the state's renewable auction mechanism to incentivize the use of firehazard wood in power generation[21]. Similarly in Alberta, Canada, where mountain pine beetle infestations have killed swathes of forest, the government has temporarily increased harvest rates to try and reduce the spread of the infestation[22]. Peak Carbon will seek opportunities to try and direct such hazardous biomass into useful bioenergy pathways.



18 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/349024/BEAC_Report_290814.pdf

19 http://www.aebiom.org/wp-content/uploads/2016/08/DG-ENVI-study-imports-from-US-Final-report-July-2016.pdf

20 https://www.fs.fed.us/pnw/sciencef/scifi117.pdf

21 https://www.pge.com/en_US/for-our-business-partners/energy-supply/electric-rfo/wholesale-electric-power-procurement/bioenergy-renewable-auction-mechanism-request-for-offers.page

22 https://www.agric.gov.ab.ca/app21/forestrypage?cat1=Mountain%20Pine%20Beetle%20in%20Alberta

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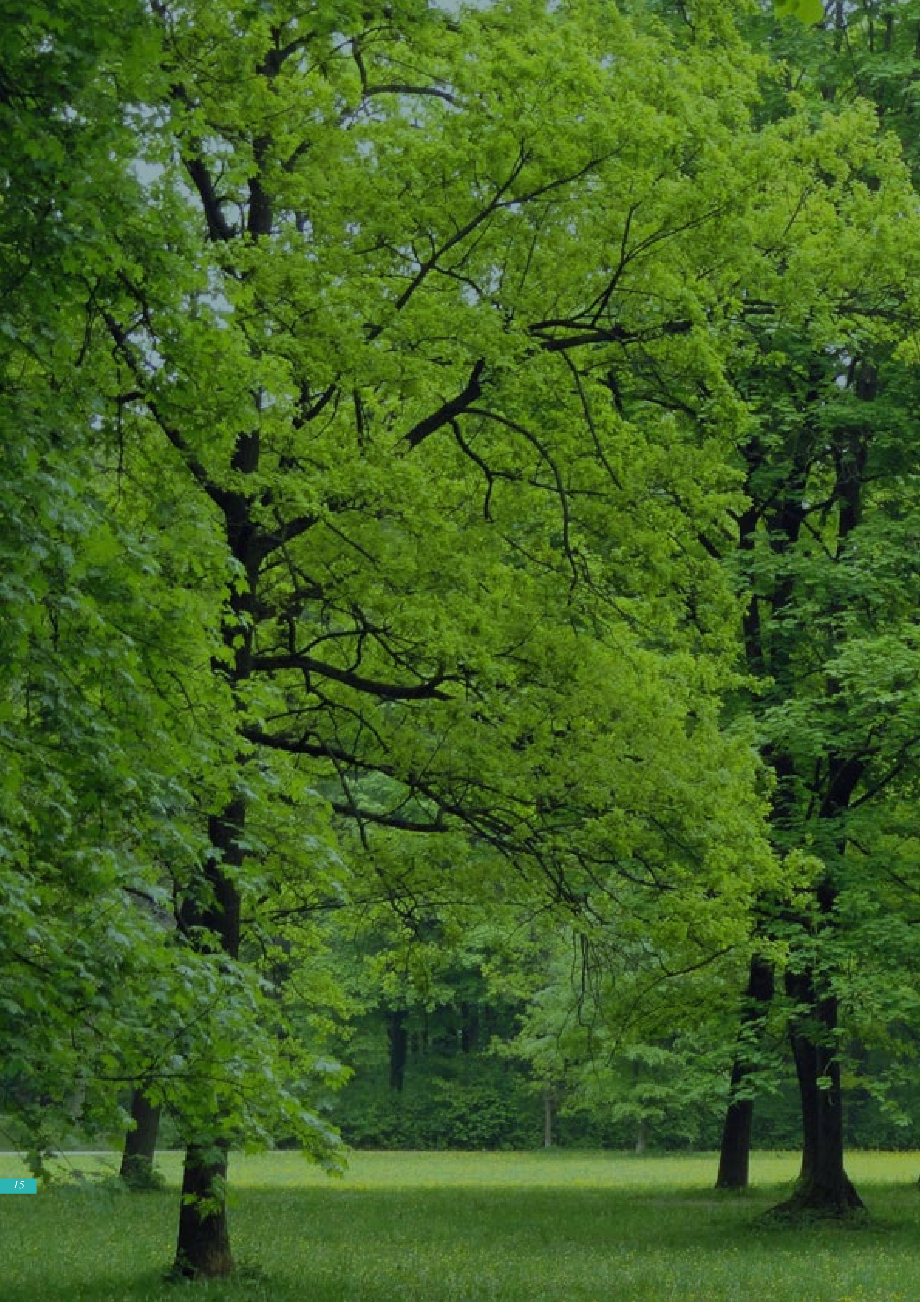

Peak Carbon will combine forest carbon protocols and biomass sourcing to ensure longevity and integrity of carbon sequestration.

Fundamental to claims of carbon neutrality for biomass is ensuring that carbon stock levels within the forest do not fall over time. Recent studies have shown that despite increasingly intensive management and a 57% increase in harvests/removals from timberland in the US South, the amount of wood/fiber stored in the forests increased 108%. On average, annual timberland growth exceeds removals by 38%[23,24].

Whilst certifications such as the Sustainable Biomass Program[25] require holders to use data to demonstrate harvest levels do not exceed forest productivity, they do not provide assurances that such levels will be maintained over time periods which ensure the initial carbon debt relative to fossil fuels are repaid and ideally ultimately exceeded.

The forestry offset protocols eligible under the California, Ontario and Quebec Cap and Trade systems are designed to ensure that carbon levels sequestered on the project area do not fall below a given baseline[26]. In order to receive the offsets a project has to provide assurances that (other than unintentional reverses such as forest fires) the carbon stock will not fall below the baseline for a period of 100 yeas from the date of offset issuance. Given the risk of invalidation of offsets and associated financial costs, Peak Carbon intends to use quantitative techniques required in the protocols to ensure baselines are not breached within the project area boundaries or surrounding land used for biomass sourcing.

23 https://blog.forest2market.com/forest2market-report-shows-increased-demand-for-wood-fiber-leads-to-forest-growth

24 https://www.drax.com/sustainability/active-management-forests-increases-growth-carbon-storage/

25 https://sbp-cert.org

26 https://www.arb.ca.gov/cc/capandtrade/protocols/usforest/forestprotocol2015.pdf

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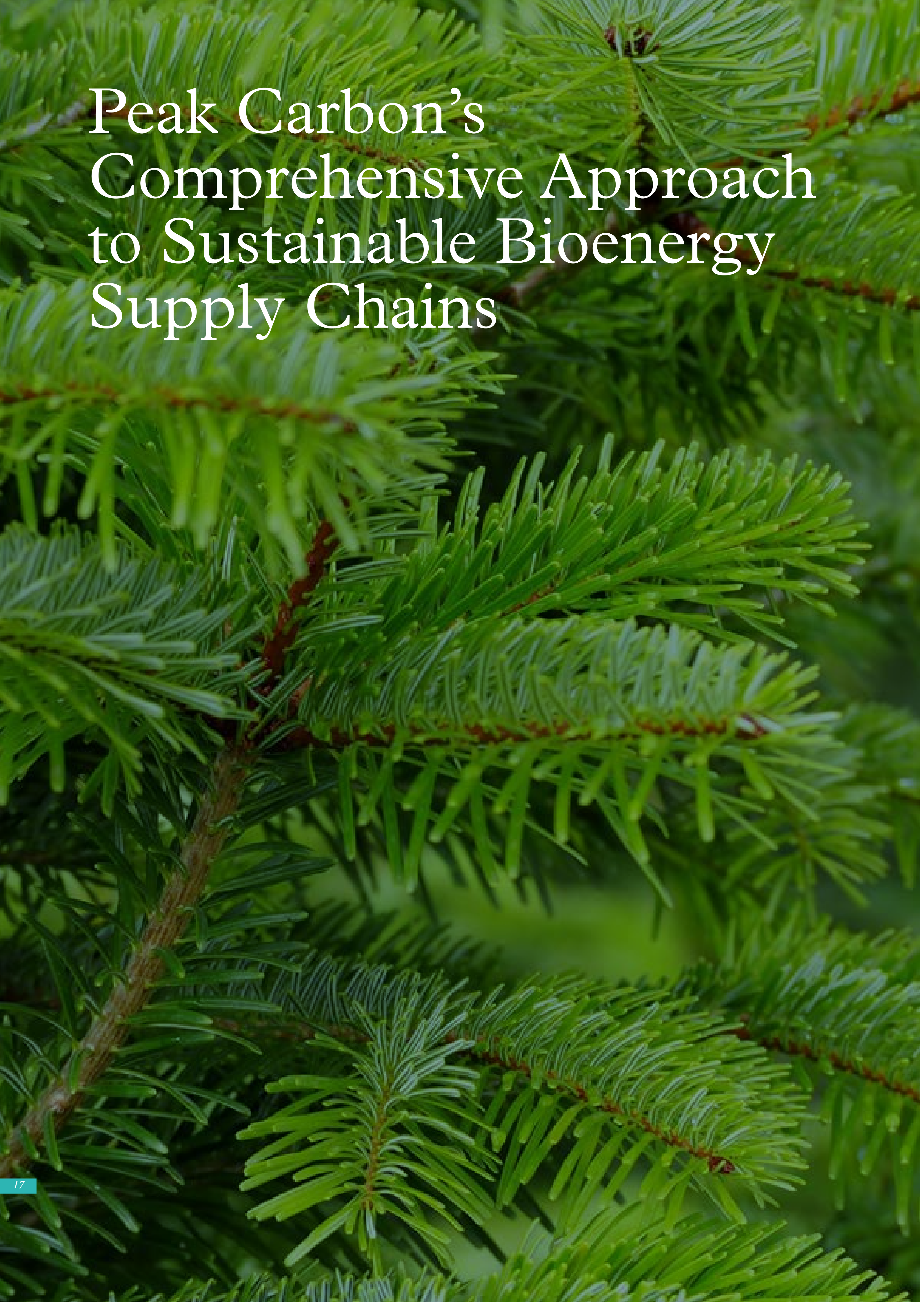
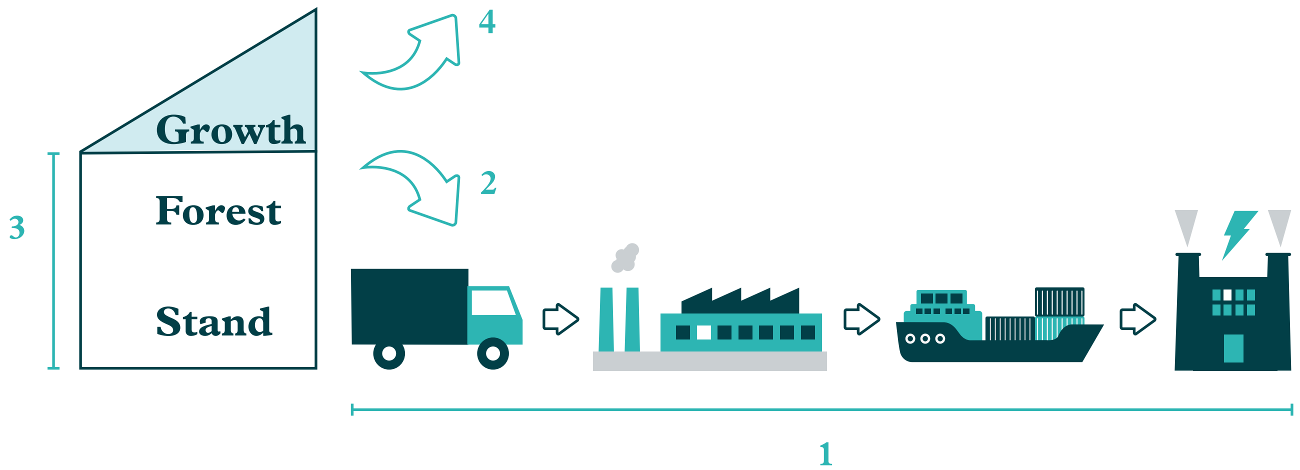


Peak Carbon's Comprehensive Approach to Sustainable Bioenergy Supply Chains

Peak Carbon's investment criteria are unique in integrating these scientific principles into a comprehensive analysis of the sustainability of the biofuel supply chain.

Forest species and management cycle specific CO_2 sequestration >= Increase in process emissions for renewable fuel vs fossil fuel displaced – CO_2/CH_4 from burnt/rotted wood



1 Process emissions for bioenergy value chain compared to displaced fossil fuel value chain to establish relative carbon debt.

2 Only thinnings, residuals and diseased/firehazard wood, with no counterfactual use, are used for bioenergy. Associated impact on relative carbon debt balances calculated.

3 Initial forest stand preserved under offset commitment.

4 Timber harvested from growth only, and only once carbon payback period has ensured lower carbon debt than displaced fossil fuel.

For each investment in biofuel production, Peak Carbon will carry out full lifecycle analysis, from the characteristics of the forest stand and associated timber management through to end use of the biofuel value chain and the fossil fuel value chain it is displacing, to ensure the scientific integrity of the emissions reduction benefits.

With the situation of each bioenergy value chain unique, it is Peak Carbon's belief that principles of this approach will have to become the required standard by regulators to ensure a positive contribution of biofuels to global climate change commitments.

Peak Carbon