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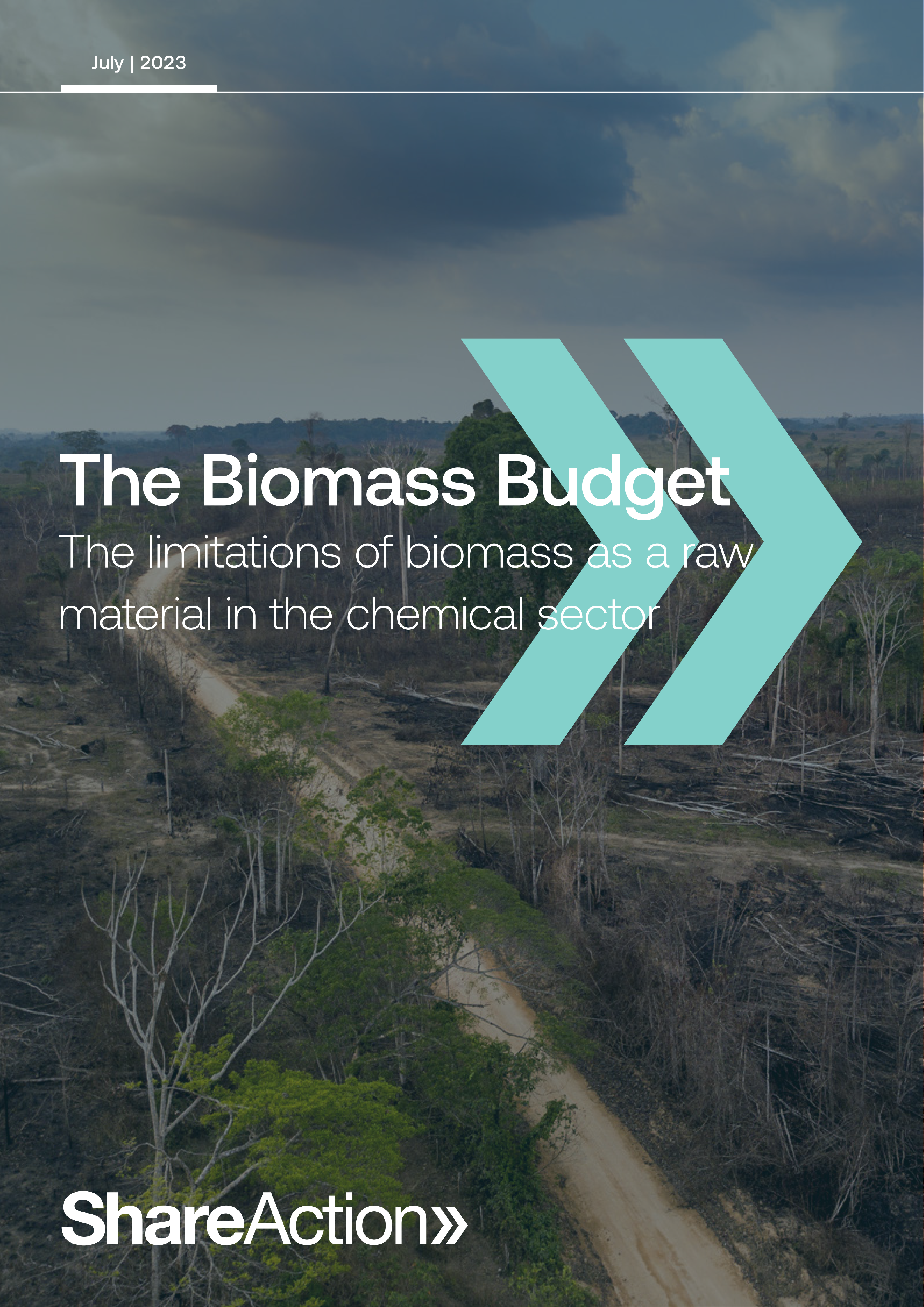

The Biomass Budget

The limitations of biomass as a raw material in the chemical sector

ShareAction»

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Executive Summary

As the source of 6.1 per cent of global greenhouse gas emissions, the chemical sector is a major driver of the deepening climate crisis[i]. Chemical companies bear a responsibility to reduce their impact on the climate, and this is the critical decade to do so.

To achieve deep and sustained emissions reductions, companies must replace fossil fuels both as an energy source and as a raw material, or 'feedstock', in chemical production. This briefing is concerned with the use of biomass as a **feedstock** in the production of the seven primary chemicals—ammonia, methanol, ethylene, and high-value chemicals ('HVCs')—which account for around two-thirds of the sector's energy use. For a discussion of biomass as an energy source, see ShareAction's briefing *The Biomass Blind Spot*.

Companies are increasingly looking to biomass—biological material derived from living or recently living organisms, usually plant matter—as an ostensibly low-carbon alternative to fossil fuel feedstocks in primary chemical production. Yet biomass is not automatically low-carbon, and it also faces other major sustainability challenges related to its intensive use of land resources and its impacts on biodiversity. As companies turn from fossil fuels to biomass, they risk creating new sources of harm to climate and nature in place of the old—and delaying the transition to truly sustainable, emissions-neutral modes of production.

In this briefing, we outline the risks of turning to biomass as an alternative feedstock, and set out how companies can minimise their exposure to these risks. We also provide a set of questions that investors can use in their engagement with chemical companies about biomass feedstocks.

Biomass is not straightforwardly carbon-neutral, renewable, or sustainable

The chemical sector needs to replace fossil fuels as a source of hydrocarbons for primary chemical production. (p. 16) There are several alternatives to fossil feedstocks, including renewable hydrogen, captured carbon, biomass, and plastic waste. Chemical companies are increasingly looking to biomass to substitute oil and gas feedstocks, on the assumption that biomass is a carbon-neutral and sustainable resource.

However, biomass feedstocks are not automatically low-carbon. (p. 15) Indeed, when emissions across the whole lifecycle of biomass feedstocks are taken into consideration, they can equal or surpass those from the use of fossil fuels.

The potential risks of biomass feedstocks extend beyond greenhouse gas emissions, to land use and biodiversity. The cultivation of biomass is land-intensive and competes with other uses of land, in particular food production. (p. 17) It can also drive deforestation and other kinds of land-use change, contributing to the widescale destruction and fragmentation of species habitats. (p. 18) Finally, biomass production can have a range of other impacts on ecosystem health, such as by causing soil erosion or by depleting local water resources. (p. 20)

Biomass should only be considered sustainable if extremely strict conditions are met during production and use (p. 21):

- **No conversion of land with high carbon stocks or high biodiversity value,** including natural forest, peatland, wetland, and natural grasslands, to biomass cultivation.
- **No competition with food production:** The conversion of arable land to biomass production should be avoided, and no biomass which could also be used as food or animal feed should be used for chemical feedstocks.
- **No competition with lower-carbon uses of biomass:** Feedstocks which can be used in lower-carbon applications such as timber construction or paper production should be reserved for those uses. Chemical feedstocks should not be derived from whole trees (roundwood).
- **Low or no emissions across the entire lifecycle of the biomass feedstock,** including cultivation, harvesting, processing, transportation, and transformation into the chemical product.
- **Regrowth periods must be respected** to protect forests' ability to sequester carbon.
- **Biodiversity and broader ecosystem health must be preserved or enhanced** in all harvesting areas.

Supply of sustainable biomass will be highly limited, and existing biomass governance does not adequately manage risks

The supply of biomass which meets the conditions listed above will be highly limited – and several sectors will compete for its use. (p. 23) Sustainable bioresources will need to be carefully allocated among competing sectors, prioritising those which face the steepest challenges to decarbonisation. (p. 24)

The chemical sector is one priority use of biomass—but demand from the chemical industry alone could outstrip sustainable supply. Conservative estimates of biomass availability in 2050 suggest that no more than 30-50 exajoules (EJ) may be available per year for energy and feedstock uses. By comparison, if the chemical industry were to source the majority of its feedstocks for virgin plastics from biomass, it alone could require 34 EJ per year—even assuming a 20 per cent demand reduction due to circularity measures. (p. 23)

Existing biomass governance is insufficient to safeguard sustainable biomass or ensure that it reaches the sectors that need it most. Current sustainability standards are highly fragmented across international borders, and are not ambitious enough to mitigate the risks associated with intensive biomass production. (p. 25) Furthermore, biomass policy in the EU and elsewhere heavily subsidises its use in low-priority sectors such as power and road transport without providing similar support for its use as a chemical feedstock, amplifying the risk that limited supply will be overstretched. (p. 25)

Chemical companies must limit their dependence on biomass feedstocks as much as possible

In view of these risks, companies must act now to avoid unnecessary dependence on biomass as they move away from fossil fuels.

First, alternative emissions-neutral feedstocks – renewable hydrogen, air or point-source captured carbon, mechanically recycled plastics, and, if strict sustainability conditions are met, a small amount of chemically recycled plastic waste – need to be adopted to limit biomass use. Any use of biomass must be integrated into a broader strategy to scale the use of more sustainable feedstocks and ultimately eliminate dependence on bioresources. (p. 38)

Second, companies should favour production processes which are compatible with a range of non-fossil feedstocks and can therefore limit dependence on biomass. There are a number of ways chemicals can be produced from biomass, and some of them could risk locking in long-term dependence on biomass.

Steam cracking, which is compatible with only a narrow range of non-fossil feedstocks, is unlikely to be a sustainable route for HVC production in the long term. (p. 31) Companies should favour processes which produce HVCs from methanol instead. These are described in our previous investor briefing, *Slow Reactions: Chemical companies must transform in a low-carbon world*.

Processes which use biomass to generate 'syngas', a mix of hydrogen, carbon dioxide, and carbon monoxide, may have a small role to play in producing emissions-neutral methanol. (p. 33) Syngas can be derived from several different sources, including renewable hydrogen, direct air and point-source carbon capture, and plastic waste as well as biomass. However, companies should not rely on biomass alone for syngas production.

Recommendations

This briefing outlines three actions chemical companies can take to minimise their exposure to the risks created by biomass feedstocks (p. 38):

1 **Minimise demand for biomass now,** by supporting the transition to the circular economy, adopting the use of non-biomass feedstocks, and investing in methanol-based HVC production.

2 **Source biomass in line with strict sustainability criteria,** as outlined in this report.

3 **Develop and implement a strategy to reduce long-term dependence on biomass,** by setting out clearly how the company plans to increase the proportion of non-fossil, non-biobased feedstocks in its feedstock mix and scale methanol-based HVC production over time.

Introduction

Introduction

The chemical sector has the means to reduce its carbon emissions now—and the risks of inaction are growing.

As we explained in our previous investor briefing, *Slow Reactions: Chemical companies must transform in a low-carbon world*, it is technologically feasible and increasingly economically viable to eliminate emissions from primary chemical production. And as the costs of fossil fuels rise and alternative technologies scale, the risks to the sector and its investors are growing. Under recent proposed changes to the EU Emissions Trading System, for example, the European chemical sector could face a doubling in its carbon costs within the next decade[ii]. Companies that stay ahead of these changes, taking the lead in adopting fossil-free production processes, could set themselves up for prolonged competitive advantage. Companies which do not could be left in their wake.

To eliminate emissions from primary chemical production, chemical companies must replace fossil feedstocks with emissions-neutral alternatives.

Roughly half of the fossil fuels used in the chemical sector are consumed as feedstock – as a source of the carbon and hydrogen atoms needed in the molecular structure of petrochemicals[iii]. Eliminating emissions from primary chemical production will require the widescale replacement of fossil feedstocks with emissions-neutral alternatives. Several alternatives exist, but some are more sustainable than others.

As the chemical sector turns away from fossil feedstocks, new risks are emerging.

Facing pressure to reduce their emissions, chemical companies are turning to biomass as a substitute for fossil feedstocks. Biomass is an attractive option for companies because it can be integrated into existing production processes. But biomass faces its own sustainability challenges, ranging from its intensive use of land to its impacts on biodiversity and food production, and widespread deployment of this resource in chemical production will not be sustainable in the short or long term. Companies need to recognise these limitations, and reduce their dependence on this scarce resource as much as possible.

Choices that chemical companies make now will determine whether chemical production can be truly sustainable and emissions-neutral by 2050.

Biomass is not the only substitute for fossil feedstocks; other feedstocks are available which do not have similar sustainability risks. But these feedstocks need to be scaled, and new technologies adopted to enable their implementation. Chemical companies face a choice: they can take steps now to ensure that chemical production is truly sustainable and emissions-neutral by 2050, or they can prolong status-quo production—reducing the use of fossil fuels, but creating new sources of harm in their place.

It is in this context that we release this briefing.

Investors have a crucial role to play in ensuring that the chemicals system in 2050 will remain within planetary boundaries. By engaging with chemical producers in detail about their use of biomass, they can ensure not only that companies take ambitious action to reduce their emissions, but that they avoid any harm to people and planet in the process.

Investors need to understand the limitations of biomass as an alternative feedstock, and recognise that it has, at most, a very small role to play in the future of primary chemicals. This briefing will survey the risks involved in biomass production, and will explain why the supply of sustainable biomass is so constrained. It will then describe how biomass can be used as a chemical feedstock, and set out actions that companies must take to avoid unsustainable dependence on bioresources. Engagement questions at the end of the report will support investors' discussions with companies about the quality of their transition plans, and about their use of biomass specifically.

Part 1:

The limitations of biomass, and their implications for the chemical sector

Part 1: The limitations of biomass, and their implications for the chemical sector

Facing increasing pressure to replace fossil fuels as raw materials in chemical production, companies are turning to biomass as the easiest alternative. **Yet while biomass is a market-ready substitute for fossil feedstocks, it is by no means a silver-bullet solution to the feedstock problem.**

Biomass faces major sustainability challenges: its production can be extremely emissions-intensive, and can put immense pressure on land resources and on biodiversity. Furthermore, the supply of truly sustainable, emissions-neutral biomass is expected to be extremely limited by 2050, the global deadline for reaching net-zero carbon emissions.

Demand from the chemical sector alone could outstrip the available supply of sustainable biomass. And existing biomass governance may not prevent the worst consequences of unsustainable sourcing.

Chemical producers must therefore minimise their use of bioresources as much as possible, and ensure that any biomass they do use is sourced according to strict sustainability criteria.

What is biomass?

In the broadest sense, biomass refers to any 'biological material derived from living, or recently living organisms', usually, though not exclusively, plant matter[iv]. Biomass has an extremely wide variety of uses, including for human food and animal feed; for textile, paper, and wood products; and, when combusted, as a source of energy. While the burning of wood has long been used as a source of heat and energy in traditional applications, the last thirty years have seen the rapid rise of modern industrial applications of biomass, which use it to produce energy for power, transportation, and heating and cooling. It is also used to supply hydrocarbons for the production of chemicals.

The scope of this briefing is to consider the use of biomass specifically as a **feedstock in primary chemical production.** Biomass should not be used as a source of energy for power and heat. For a discussion of these applications, see ShareAction's briefing *The Biomass Blind Spot*.

Box 1: What are primary chemicals?

The seven primary chemicals are ammonia, methanol, and the so-called 'high-value chemicals' (HVCs), which include ethylene, propylene, benzene, toluene, and xylene. Ethylene and propylene are commonly called 'olefins', while benzene, toluene, and xylene are called 'aromatics'. Primary chemicals have traditionally been made from fossil fuels such as oil and gas.

While primary chemicals can be sold as end products themselves, they also serve as key building blocks in the production of a vast array of other chemicals. For this reason, primary chemicals account for around two-thirds of the chemical sector's energy use[v], and are the focus of this report. However, the biomass sustainability criteria we discuss below apply to biomass sourced for the production of any chemicals, not just primary chemicals.

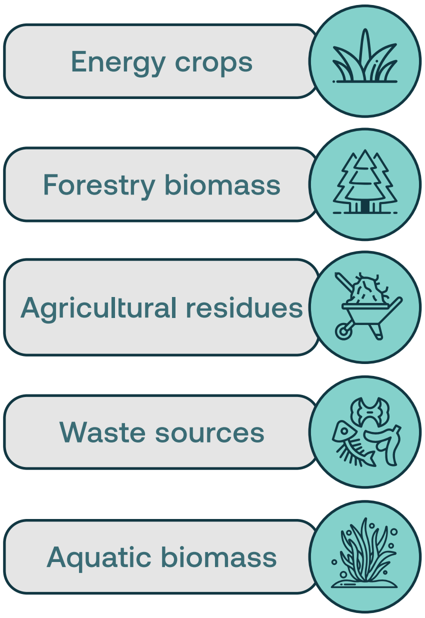
There are five main types of biomass which can be used as chemical feedstocks. These include energy crops, forestry biomass, agricultural residues, municipal and industrial wastes, and aquatic biomass.

- **Energy crops**[1] are cultivated crops grown specifically for industrial energy and chemical applications, usually to be turned into biofuels such as ethanol, biodiesel, or biogas. 'First-generation' energy crops are crops which could also serve as food or animal feed, and which require arable land to produce, such as corn, sugarcane, soybean, rapeseed, and palm[vi]. 'Second-generation' energy crops are non-edible crops such as miscanthus (silvergrass) and willow, which can be grown on lands not suitable for agriculture[vii].
- **Forestry biomass** refers to a range of materials which are harvested from forests or industrial tree plantations. It can include roundwood (wood from the trunk of a tree), 'forestry residues' such as small branches, bark, and thinnings left over from wood harvesting[viii], and industrial processing wastes such as sawdust and trimmings from sawmills as well as black liquor, a by-product of the paper production process[ix].
- **Agricultural residues** are by-products of the harvesting and processing of crops for agricultural purposes, such as straw, stalks, husks, and bagasse (from sugarcane)[x].

1 While this briefing is concerned with the use of biomass as a chemical feedstock, not an energy source, 'energy crop' is the term most commonly used for this kind of biomass in the literature and will therefore be used here.

- **Municipal and industry wastes** include the organic portion of household waste, waste oils and fats (especially waste cooking oils), sewage sludge, and livestock manure[xi].
- **Aquatic biomass** includes macroalgae (seaweed) and microalgae (phytoplankton). While they may provide a significant source of supply in the future, the scalability of aquatic biomass for industrial uses faces significant uncertainty, so they will not be discussed in detail in this briefing[xii].

Figure 1: Types of biomass feedstock



Companies are turning to biomass as a carbon-neutral alternative to fossil feedstocks, but biomass is far from automatically low-carbon

The recent turn to biomass feedstocks in the chemical sector has been motivated by the assumption that biomass is a sustainable and emissions-neutral replacement for fossil fuels. This assumption is based on the idea that the carbon emitted during the production, use, and disposal of chemical products will be resequestered by new plant growth, so there will be no net increase in carbon dioxide in the atmosphere.

However, the actual balance between carbon emitted and carbon sequestered is much more complex than this theory would suggest. The assumption that biomass is emissions-neutral ignores the fact that it can take time for the carbon emitted during chemical production to be recaptured by new plant growth. When biomass is not allowed time to regrow fully prior to harvesting, the total amount of carbon sequestered in the area of biomass production will decline, resulting in a net increase in climate-warming gases in the atmosphere. The carbon-neutrality thesis also ignores numerous other potential sources of emissions during the lifecycle of the bio-based product, such as land-use change, the depletion of soil organic carbon during cultivation and harvesting, and the use of fossil fuels in the processing and transportation of feedstocks, as discussed below. In fact, there is no guarantee that the use of biomass as a chemical feedstock will reduce emissions at all compared to the use of fossil fuels[2]. Strict conditions must be met during the entire lifecycle of the biomass feedstock for it to be emissions-neutral.

Box 2: Why does the chemical sector need to end the use of fossil feedstocks, and what are the alternatives?

The use of fossil fuels as feedstocks in chemical production leads to emissions at several points in the chemical value chain:

- Upstream, fugitive[3] emissions are created during the extraction and transportation of fossil fuels.
- During production, any carbon which is not required for the molecular structure of the relevant chemical is released into the atmosphere. In the case of chemicals which do not require any carbon in their molecular structure, such as ammonia, all of the carbon contained in the fossil feedstock will be emitted.
- If carbon is required for the molecular structure of the desired chemical, this carbon will be released downstream, for example when plastics derived from methanol or HVCs are incinerated.

Companies cannot rely on other parts of the value chain to reduce feedstock emissions. Fugitive emissions from upstream extraction and transportation are significant[xiii], and, downstream, there are limits to the reusability and recyclability of plastics and other petrochemical products[xiv].

3 Unintentional emissions, e.g. leakage during the extraction and transportation of fossil fuels.

2 One study, for example, found that the global warming potential of plastic bottles derived from 30% bio-based polyethylene was comparable to or slightly higher than that of petrochemical-based plastic bottles, depending on the biomass feedstock used. European Commission (2021). *Environmental Impact Assessments of Innovative Bio-based Product: Task 1 of "Study and Support to R&I Policy in the Area of Bio-Based Products and Services"*, pp. 206, 219. Available online at https://op.europa.eu/en/publication-detail/-/publication/15bb40e3-3979-11e9-8d04-01aa75ed71a1 [accessed 13 March 2023].

In order to reduce emissions across all scopes, fossil fuels must be replaced by feedstocks that are zero-emissions or emissions-neutral on a lifecycle basis. For example, renewable hydrogen can be produced through a process called electrolysis, which splits water molecules into hydrogen and oxygen atoms using renewable energy. Renewable hydrogen is discussed in our previous investor briefing, *Beyond the Blue: Renewable Hydrogen in the Chemical Industry*.

Where carbon feedstock is required, as it is for methanol and HVCs, it must be sourced from carbon that is already in circulation, to avoid a net increase in emissions to the atmosphere. Alternative sources of carbon include biomass, plastic waste, and carbon captured directly from the air ('direct air capture', or 'DAC') or from as-yet-unavoidable industrial emissions ('point-source capture'). While renewable hydrogen is increasingly available and competitive with fossil alternatives[xv], there is currently no silver-bullet substitute for fossil sources of carbon. Plastic waste is limited in supply and faces challenges in decoupling fully from fossil fuels, as discussed in our previous investor briefing, *Coming Around: How chemical companies must adapt to the circular economy*. Biomass is also highly limited in supply, and its production involves major sustainability risks, as discussed below. And captured carbon is not yet available at scale.

Because of these challenges, a range of feedstocks will need to be adopted during the transition to net-zero chemical production. However, chemical companies should favour feedstocks with the lowest sustainability risks – renewable hydrogen and captured carbon.

Biomass poses clear risks to land availability, climate, and biodiversity

Biomass cultivation is highly land-intensive, and competes with other uses of land

The production of biomass is extremely land-intensive, and land is a scarce resource with many competing uses. Many bioenergy crops, such as corn, sugar, soy, and rapeseed, need to be grown on arable land, and can therefore compete with food production. Several studies have suggested that the rising demand for bioenergy has been an important contributor to global food insecurity, both by directly diverting resources away from food production and by inflating the price of key food staples such as corn and sugar[xvi].

The cultivation of biomass can drive deforestation and other land-use change. Land-use change can be both directly and indirectly caused by the expansion of biomass production. Direct land-use change occurs where biomass production directly supplants another use, such as when natural forest is cut down to make way for bioenergy production. Indirect land-use change (iLUC) occurs when the use of land for biomass production triggers land-use change elsewhere, for example when the expansion of biomass production into agricultural land causes natural forest to be converted to food production[xvii].

The conversion of natural landscapes to new uses leads to high levels of emissions. Natural landscapes such as forests, peatland, and grassland provide some of the world's most important carbon sinks, fixing vast amounts of carbon in living plant and animal matter and, especially, in their soils. When these landscapes are converted to produce biomass, most of this carbon, sequestered over thousands of years, is released into the atmosphere. The emissions resulting from such land-use change usually far outstrip the benefits of replacing fossil fuels with biogenic alternatives over relevant timescales[xviii].

Land-use change also has major consequences for biodiversity. Worldwide, biodiversity is declining at the fastest rate in human history; around 25 per cent of animal and plant species globally are threatened with extinction, many within decades[xix]. The single most important factor driving species loss is the destruction of habitats due to land-use change[xx]. The conversion of species-rich natural landscapes to agricultural production is a particularly serious concern[xxi], but the conversion of natural forests to industrial management can also have severe implications for biodiversity. Woody biomass harvesting can affect important features of the forest ecosystem such as the composition of tree species, the relative age of individual trees, and the amount of deadwood left on the forest floor, while certain intensive forestry practices such as clear-cutting destroy habitats completely[xxii].

Demand for land is projected to expand in the next three decades as global populations grow and become wealthier. This is highly likely to drive further land-use change[xxiii]. In order to prevent unnecessary pressure on land, the total amount of land dedicated to bioenergy crop production will need to be strictly limited. Studies suggest that no further agricultural land can be converted to bioenergy crop production before 2050 unless a substantial shift in global dietary patterns or the development of new agricultural technologies frees up agricultural land for other uses[xxiv]. Any expansion in biomass production must therefore take place only on marginal or degraded lands which are not suitable for agriculture[xxv].

The cultivation, harvesting, transportation, and processing of biomass feedstocks can lead to high levels of emissions if not carefully managed

While land-use change is the largest potential source of emissions in the lifecycle of biobased feedstocks, emissions can occur at numerous other points during the cultivation, harvesting, processing, and transportation of biomass. In particular, intensive land management practices can have a significant negative impact on the ability of a piece of land to sequester carbon. In the case of agricultural biomass, for example, the frequent disruption of soils during cultivation and harvesting[xxvi] and the overextraction of residues such as straw, husks, and nutshells[xxvii] can lead to the depletion of soil organic carbon over time.

In the case of woody biomass, intensive harvesting practices can result in significant loss of forest 'carbon stocks', or the total amount of carbon stored in a given forest. This is discussed in further detail in Box 3.

Box 3: Woody biomass and the carbon balance

The harvesting of woody biomass can have major consequences for forests' ability to sequester carbon, and can lead to high levels of net emissions if not carefully managed[xxviii]. For this reason, chemical companies which choose to use woody biomass feedstocks must source their feedstocks with extreme care.

The use of woody biomass for energy or for chemical feedstocks adds carbon to the atmosphere which may not be able to be removed within climate-relevant timescales. The theory that the use of biomass as a chemical feedstock can be emissions-neutral depends on the assumption that the carbon emitted during the processing of biomass can be resequestered through new plant growth. But whereas energy crops such as corn and sugarcane grow back relatively quickly, it takes many years for a young tree to capture the carbon released by the combustion of a mature tree (the so-called 'carbon payback period'). When trees are not given adequate time to regrow following harvesting, the result will be a long-term decline in the amount of carbon a forest is able to store. Carbon payback periods depend on the species of tree and the type of forest from which it was harvested, but can range from decades to centuries[xxix].

Strict criteria must be applied to any woody biomass used as chemical feedstocks to limit their climate impacts. Because natural forests are such important global carbon sinks, in addition to being home to some of the world's richest ecosystems, wood harvesting should occur exclusively in existing managed forests. Furthermore, woody biomass used in chemical production should be limited to industry and forestry residues which have short carbon payback periods and which cannot be used in lower-carbon applications, for example paper production or wood construction. These include industry wastes such as sawdust, shavings, offcuts, and 'black liquor' (a by-product of the pulping process)[xxx], and harvesting residues such as treetops, bark, small branches, and narrow-diameter thinnings. Roundwood, which represents growing forest carbon stock, should not be used for chemical feedstocks, and stumps should also be avoided to preserve soil carbon levels and protect biodiversity[xxxi].

In addition, forests need to be managed to maximise their ability to store carbon over the short and long term. This means allowing adequate amounts of time for trees to regrow following their harvesting. Regrowth periods vary depending on the region and tree species, but can be as long as 150 years for species commonly used in managed forestry[xxxii]. Clear-cutting, which causes the carbon levels of a forest to fluctuate dramatically over time, should also be avoided, and enough residues allowed to remain on the forest floor following harvesting to maintain levels of soil organic carbon.

The use of fossil fuels during the cultivation, harvesting, processing, and transportation of biomass feedstocks is another significant source of lifecycle emissions. Due to its high water content, raw biomass often requires extensive treatment prior to use, and the heat and other energy needed for this treatment is often supplied by fossil fuels (or biomass). The use of fossil fuels to power heavy machinery during cultivation and harvesting can contribute further emissions, as can the transportation of raw or treated biomass across long distances. One study looking at wood pellets transported from the southeastern US to the Netherlands for power generation estimated that emissions from transportation and pelletising alone amounted to 322 kg CO_2 per tonne of pellets—as much as one-sixth of the emissions produced by combustion[xxxiii].

The cultivation of biomass can also have wider impacts on ecosystems and communities

Biomass cultivation and harvesting can pose a number of other risks to ecosystem health:

- *Water demand.* Bioenergy crops can be highly water-intensive. Where water demand is not properly managed it can put excessive stress on local freshwater supplies[xxxiv]. This will become an even more serious concern as global temperatures continue to rise, leading to higher rates of evaporation from croplands.
- *Eutrophication*. Heavy use of fertilisers can lead to algal blooms in regional waterways, which can trigger effects including ocean acidification and the decline of fresh- and seawater wildlife populations, with further ramifications for the communities dependent on those resources[xxxv].
- *Soil health*. Frequent planting and harvesting can deplete soil nutrient content as well as emitting carbon into the atmosphere[xxxvi]. It can also cause soil erosion, especially in the case of annual crops such as corn and sugarcane.

Municipal and industrial wastes are some of the most sustainable sources of biomass, but high demand could overstretch supply

Waste sources, including municipal solid waste and agricultural and industrial wastes, are among the least land- and carbon-intensive sources of biomass. Companies should prioritise these over virgin sources of biomass.

However, even assuming substantial improvements to current waste collection infrastructure, biomass demand cannot be met entirely by waste. Any excess demand would then need to be supplied by virgin resources. For example, studies have predicted that recent US bioenergy policies supporting the rollout of renewable diesel, a transport biofuel that can be produced from waste sources such as used cooking oil, could result in millions of tonnes of additional vegetable oil production – and the conversion of tens of thousands of hectares of forested land as a consequence[xxxvii].

Biomass must meet extremely strict criteria to be considered sustainable

To minimise risks to land, climate, and biodiversity, biomass should only be considered sustainable if strict conditions are met over the entire lifecycle of the biomass feedstock (Table 1).

There are six overriding principles:

- **No competition with food production:** The conversion of arable land to biomass production should be avoided, and no biomass which could be used as food or animal feed should be used for chemical feedstocks.
- **No conversion of land with high carbon stocks or high biodiversity importance,** including natural forest, peatland, wetland, and natural grasslands, to biomass cultivation.
- **No competition with lower-carbon uses of biomass:** Feedstocks which can be used in applications which enable long-term sequestration of carbon (for example, timber construction) or the displacement of high-emitting materials (for example, the use of paper as a substitute for plastic packaging) should be reserved for those uses. Forestry biomass used for chemical feedstocks should be limited to industry wastes and harvesting residues with short payback periods.
- **Low or no emissions across the entire lifecycle of the biomass feedstock,** including cultivation, harvesting, processing, transportation, and transformation into the chemical product.
- **Regrowth periods must be respected** to protect forests' ability to sequester carbon.
- **Biodiversity and broader ecosystem health should be protected** in all harvesting areas.

Table 1. Sustainability criteria for biomass feedstocks

General principles	• Prioritise waste-derived biomass over virgin materials • No conversion of land with high carbon stocks, including natural forests, peatlands, and natural grasslands, to biomass production or harvesting • No conversion of land of high biodiversity importance, including highly biodiverse forests, wetlands, and grasslands, or any preserved natural ecosystems, to biomass production or harvesting • Quantify and minimise emissions across the entire lifecycle of the bio-based feedstock (cultivation, harvesting, processing, transportation, and chemical production)
Energy crops	• No first-generation energy crops, such as palm, soy, corn, sugarcane, and rapeseed, which could compete with food production • No conversion of arable land to biomass production • Maintain or increase soil carbon levels • Minimise water and agrochemical use • Avoid invasive species
Forestry biomass	• Limit feedstocks to industry wastes and harvesting residues with short payback periods; avoid diverting residues away from lower-carbon uses (e.g., wood products or paper) • Allow a portion of residues to remain on forest floor to protect soil carbon levels and biodiversity; precise amount dependent on location • Maintain or increase above- and below-ground carbon stocks; respect species-specific regrowth periods • Protect biodiversity by planting diverse, non-invasive species, avoiding agrochemicals, and allowing for portions of unmanaged land for species habitats and wildlife corridors
Agricultural residues	• Allow a portion of residues to remain in the ground to protect soil carbon levels; precise amount dependent on location • Avoid diverting residues away from other uses, e.g. animal bedding

Figure 2: What is sustainable biomass?

Adapted from Energy Transitions Commission (2021)

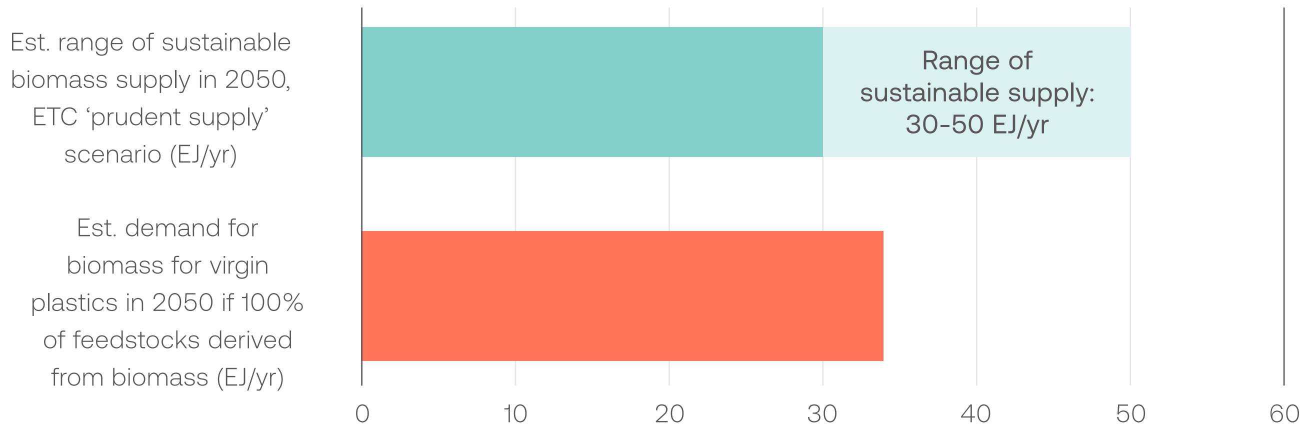
Sustainable biomass will be a highly limited resource, and many sectors will be competing for its use

Biomass is not an infinite ‘renewable’ resource. There is a limit to the amount of biomass that can be used for industrial purposes without putting unsustainable pressure on constrained land resources and risking high levels of emissions and biodiversity loss[xxxviii]. The precise amount of sustainable biomass that will be available by 2050 will be determined by a complex range of factors, and projections of future supply range widely, depending on assumptions about land availability and the stringency of the sustainability criteria applied. However, growing concerns about global biodiversity loss and an increasing recognition of the potential scale of non-energy uses of biomass have prompted a significant downward revision of estimates of supply in the last few years[xxxix]. This briefing bases its conclusions on these more conservative estimates, in particular that of the Energy Transitions Commission (ETC), which applies strict sustainability criteria aligned with those laid out above.

The ETC’s ‘prudent supply scenario’ suggests that no more than 40–60 exajoules (EJ)[4] of sustainable biomass may be available per year by 2050, with only 30–50 available for industrial energy and feedstock uses. If the chemical industry were to source 100 per cent of its feedstocks for virgin plastics from biomass, it alone would require 34 EJ of biomass—even assuming a 20 per cent demand reduction due to circularity measures, a relatively optimistic assumption[xl]. In other words, demand from the chemical sector alone could overstrain the supply of sustainable biomass, with significant consequences for the climate and nature.

4 Biomass used for bioenergy and chemical feedstocks is usually measured in exajoules (a unit of energy) rather than by weight.

Figure 3: Demand for biomass for virgin plastic production in 2050 could exceed sustainable supply



Source: Energy Transitions Comission (2021)

At the same time, demand for bioenergy is projected to grow rapidly as the global economy decarbonises and heavy-emitting sectors such as aviation, long-distance shipping, and power generation look to biomass as a means of decarbonising their own operations[xli]. One commonly cited study foresees that demand for biomass within EU industries could outstrip supply by 40–100 per cent[xlii]. If unlimited use of bioresources across all sectors is permitted, excess demand could be pushed to less sustainable markets, increasing the risk of adverse impacts on land, climate, and ecosystems.

Limited supply of sustainable biomass will need to be reserved for the highest priority uses of biomass; the chemical industry is one priority sector among others

Sustainable bioresources will need to be carefully allocated among competing sectors, prioritising those which permit the lowest carbon uses of biomass and those which face the steepest challenges to decarbonisation without it[5].

The use of biomass in the construction of wood buildings, in pulp and paper products, and in novel fibre-based applications constitute the lowest-carbon uses of biomass and should be prioritised over feedstock and energy uses[xliii]. The use of timber for construction,

5 The hierarchy of use-cases in this section is based on analyses by Material Economics and the ETC. Material Economics (2021). *EU Biomass Use in a Net-Zero Economy: A Course Correction for EU Biomass*, pp 43-45, p. 69. Available online at: https://materialeconomics.com/latest-updates/eu-biomass-use [accessed 15 March 2023]; Energy Transitions Commission (2021). *Bioresources within a Net-Zero Emissions Economy: Making a Sustainable Approach Possible*, p. 62-82. Available online at: https://www.energy-transitions.org/wp-content/uploads/2022/07/ETC-Bioresources-Report-Final.pdf [accessed 10 March 2023].

for example, permits long-term sequestration of carbon in buildings, and can supplant the use of carbon-intensive steel and cement. Paper can be used as a replacement for plastic in packaging, thereby reducing demand for virgin fossil fuels.

The next highest priority use of biomass will be in sectors in which non-biobased substitutes for fossil fuels are not yet technologically proven or may not be cost-competitive with biomass in 2050. This includes the chemical industry and aviation, both of which are likely to see biomass playing an important role up to 2050[xliv]. Nonetheless, these sectors will need to adopt other decarbonisation options alongside biomass in order to avoid excess strain on supply.

Low-priority sectors include power generation, road transport, and building heating, which account for much of current bioenergy consumption[xlv]. While some specific biomass applications may be required in cases where electrification is difficult, in most cases alternative options for decarbonisation are already commercially available and are or will soon be cost-competitive with bioresources[xlvi].

Existing bioeconomy policies do not ensure optimal allocation of limited supply

Existing biomass policies heavily subsidise the use of biomass in low-priority sectors and do not offer similar levels of support for materials and feedstock uses of biomass. The EU's Renewable Energy Directive (RED) provides strong financial incentives for the use of bioenergy in power generation, building heating, and road transportation; this remains the case even in the most recent version of the directive (RED-III), which has yet to become law. Financial incentives of a similar scale do not yet exist for wood-based products or bio-based chemicals.

Such policies threaten to divert biomass away from the most efficient and lowest-carbon uses, and drive up overall levels of biomass use[xlvii]. Policy makers need to put in place holistic bioeconomy frameworks ensuring, first, that feedstock and energy uses of biomass do not compete with its use in low-carbon materials sectors, and, second, that support for the use of biomass in feedstock and energy applications focuses on the highest-value sectors, including chemicals.

Existing sustainability standards do not adequately mitigate sustainability risks

Existing biomass sustainability standards do not adequately address the risks to climate, food security, and biodiversity associated with biomass production and use. There is currently no international standard governing the sustainability of biomass supply chains, and while some exist at the national and federal levels, these vary widely in scope and quality[xlviii]. Many key regions of biomass production have very little regulation or oversight of land management practices at all. As a consequence, the sustainable sourcing of biomass across international borders is extremely challenging.

Even the most ambitious standards, such as the EU RED, may not prevent significant levels of emissions and further biodiversity loss. The RED, which sets out the sustainability criteria for any biomass used to count toward member states' national renewable energy targets, is one of the most important standards governing sustainable biomass sourcing, and serves as the basis for the certification schemes used by many chemical companies to verify the sustainability of their products. The sustainability criteria contained in the current version of the RED (called 'RED-II')[xlix] include elements of leading practice, and proposed revisions to RED-II[l], which have yet to become law, improve on these in some areas. Nonetheless, in many areas the RED criteria lack the ambition and precision necessary to mitigate fully the risks of unsustainable biomass production. Some key areas of oversight include the following:

- **Direct land-use change:** The RED-II introduced restrictions on the conversion of land with high carbon stocks and high biodiversity value to the production of agricultural biomass, and the draft version of the RED-III has extended these to forestry biomass. However, the scope of these restrictions remains too narrow, and they contain exception clauses which significantly reduce their effectiveness (Articles 29.3, 29.4, 29.5).
- **Indirect land-use change:** The RED-II and the proposed RED-III place few restrictions on the use of arable land for bioenergy crop production, an important factor driving indirect land-use change.
- **Competition with food production:** The RED-II and proposed RED-III continue to support the use of food and feed energy crops to produce biofuels.
- **Forestry criteria:** Sustainability criteria do not adequately address the impact of biomass harvesting on forest carbon stocks. While the draft RED-III has introduced some restrictions on the types of forestry biomass that can qualify for subsidies, these are too limited to prevent the diversion of material away from higher-value uses. There is no specific requirement that carbon stocks be preserved at the sourcing area level, nor that biomass producers respect regrowth periods.

EU regulation currently lacks any sustainability standard applying specifically to biomass used for chemical feedstocks. Sustainability criteria specifically tailored to the chemical sector, for example restricting the types of biomass which can be used for chemical production, will need to be developed to ensure that the sector's use of biomass remains within sustainable limits[li].

Monitoring and enforcement mechanisms must be strengthened in order to prevent unsustainable land management

Existing systems for monitoring biomass supply chains and enforcing sustainability standards are highly flawed. At the moment, the primary means of determining compliance with sustainability regulation is through third-party certification schemes such as International Sustainability and Carbon Certification (ISCC) and the Sustainable Biomass Program (SBP). These schemes vary widely in quality, and some have been criticised for weak verification procedures, lack of transparency, and insufficient levels of ambition in their sustainability criteria[lii]. These schemes will need to be standardised according to a high degree of ambition, and flaws in enforcement mechanisms (such as the absence of requirements for field verification of sourcing areas) will need to be addressed. Certification schemes should also ensure that supply chains are traceable and transparent across the entire lifecycle of the biomass feedstock.

In the medium to long term, third-party certification can be supplemented by novel data collection and data sharing technologies, which will help strengthen enforcement and facilitate a higher degree of public accountability for biomass supply chains[liii]. However, these technologies do not yet exist at scale. Emergent technologies which could be used in this way include satellite mapping and drone monitoring to track illegal harvesting and remote carbon sensing to measure changes in carbon stocks at the sourcing area level. The establishment of publicly available databases disclosing information about biomass supply chains across international borders would ensure greater accountability among biomass suppliers.

Box 4: Why certification doesn't guarantee the sustainability of biomass feedstocks

In late 2022, the BBC released a Panorama documentary detailing an investigation into the sourcing practices of the UK company Drax, the largest biomass-for-energy company in the UK and supplier of 12 per cent of the UK's 'renewable' energy[liv]. Drax is a major consumer of wood pellets, burning around 8.3 million tonnes per year, equivalent to about 16.6 million tonnes of wood—more than 150 per cent of the UK's total wood production per year[lv]. 100 per cent of this wood is imported, primarily from the US, Canada, and the Baltic states.

The investigation focused on one of Drax's wood pellet plants in British Columbia, where raw wood is processed into biomass pellets ready for combustion. It found that, despite Drax's claims to have sourced its pellets entirely from sawdust and forestry residues from 'well-managed, well-regulated forests only harvested for timber', the company was in practice using large amounts of high-quality roundwood that had been clear-cut in old-growth primary forest. Drax itself owned the logging licences in these forests.

On its website, Drax claims that all of its biomass pellets comply with UK criteria for sustainable biomass, and that 98 per cent have been approved by the leading woody biomass sustainability certification scheme, the Sustainable Biomass Program (SBP)[lvi]. How could wood pellets sourced from clear-cut primary forest have qualified as sustainable under this scheme? One study carried out by the Natural Resources Defense Council, a leading US environmental organisation, identified major flaws in the SBP's current certification system which could easily lead to bad practice of this kind[6, lvii]:

- **Inadequate verification procedures:**
    - The SBP standard almost never requires field inspections of sourcing areas. Except in rare cases, they use regional risk assessments which depend heavily on compliance with local regulation—even where local regulation does not meet the SBP's own standard.
    - Third-party verification of forest carbon accounting is not required; biomass providers are allowed to submit data based on their own assessments.
- **Weak criteria relating to forest carbon accounting, sustainable forest management, and biodiversity:**
    - Carbon accounting criteria do not include impacts on forest carbon stock. Providers are allowed to submit data related to regional carbon stocks rather than forest-specific ones.
    - The feedstock standard does not explicitly prohibit harvesting in old growth forest, and the criteria excluding feedstocks from high-carbon areas are too weak to prevent logging in these areas.
    - Criteria relating to sustainable harvesting are vague and permit harvest rates higher than regrowth rates.
    - Key biodiversity-related criteria are either entirely absent or too weak to be effective. For example, the standard lacks explicit protection for endangered species and their habitats, as well as for high conservation value forests.

Investors should be wary of assuming that certification of a company's feedstock by one of these certification schemes means that it is actually emissions-neutral or has been harvested sustainably. It is essential that investors engage with companies in detail about their sourcing practices to ensure that they are following best practice in their biomass sourcing.

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6 The SBP's current sustainability standards were published in 2015; an updated set of standards is currently under review and should be released in 2023.

In view of these challenges, the chemical industry must minimise its use of biomass feedstocks as much as possible

Chemical companies must avoid overdependence on biomass. As discussed above, the chemical industry's demand for biomass feedstocks for plastics production alone could outstrip limited supply, and the absence of robust policies allocating scarce resources to the chemical industry increases the risk that supply will be overstretched. It is therefore imperative that companies minimise their reliance on biomass to the greatest extent possible. To do this, companies will need to adopt a diverse range of emissions-neutral feedstocks, and initiate a transition away from production processes which could lock in long-term dependence on scarce biomass resources. This will be discussed in detail in the next two parts of this briefing.

Part 2:

The limited role biomass could play in primary chemical production

Part 2: The limited role biomass could play in primary chemical production

As discussed in the previous section of this briefing, the constraints on supply of sustainable biomass mean that companies need to minimise their use of bioresources as much as possible. **They therefore need to make appropriate decisions about the bio-based technologies and production processes in which they choose to invest.** There are many ways of producing primary chemicals from biomass feedstocks, and some of them require heavier dependence on biomass than others. This section will give an overview of how biomass can be used to produce primary chemicals, and will identify which processes should be favoured if chemical companies choose to make investments in bio-based production.

There are several routes for the production of primary chemicals from biomass feedstocks; some are preferable to others

There are many ways of producing methanol and high-value chemicals from bio-based feedstocks. The production processes which are the focus of this briefing[7] can be grouped into two general categories: first, steam cracking processes, which are used to make HVCs; and, second, processes which use biomass to produce a mixture of hydrogen, carbon dioxide, and carbon monoxide, called 'syngas', which can then be converted to methanol and, subsequently, HVCs. Routes for producing syngas from biomass include biomethane steam reforming and gasification.

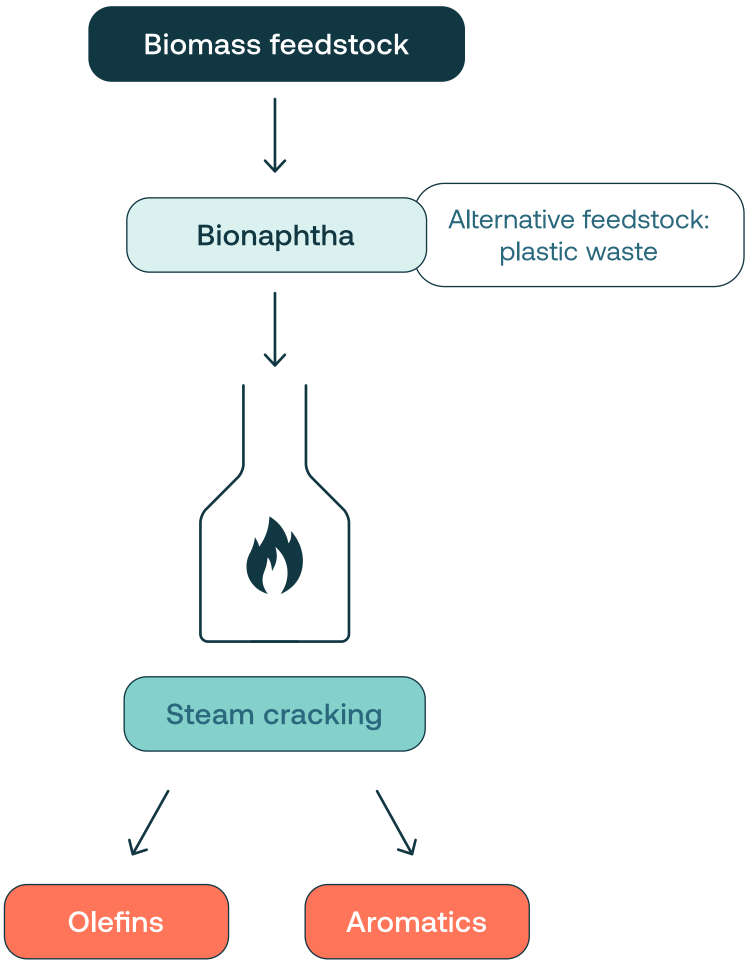
Steam cracking to produce HVCs: Existing processes can be converted to biomass feedstocks, but this would entail heavy dependence on bioresources

Steam cracking is the established route for dedicated HVC production in Europe. In the conventional process, 'naphtha', a byproduct of oil refining, is heated to very high temperatures (750C–900C) in the presence of steam in order to break long-chain hydrocarbons into smaller molecules. Steam cracking is extremely energy-intensive and emits large volumes of carbon dioxide and methane[lviii].

7 Bio-based production processes which have been deemed out of scope for this briefing include the fluid catalytic cracking of bio-oil to yield aromatics and ethanol dehydration to yield ethylene. The first occurs upstream of the production processes discussed in this briefing (Vasiliki Zacharopoulou et al. (2018), 'Olefins from Biomass Intermediates: A Review', *Catalysts,* 8: 2. Available online at: https://doi.org/10.3390/catal8010002 [accessed 31 March 2023]). The second is unlikely to be of relevance in Europe, which lacks access to cheap ethanol feedstocks (SYSTEMIQ (2022). *Planet-Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy*, p. 90. Available online at: https://www.systemiq.earth/wp-content/uploads/2022/10/Main-report-v1.22.pdf [accessed 08 March 2023]). Because our focus is on primary chemical production, we have also excluded fermentation-based biomaterials such as polylactic acid from our discussion.

As chemical companies have faced increasing pressure to reduce emissions, many are turning to biomass as a drop-in replacement for fossil naphtha in existing steam crackers. Bionaphtha, a byproduct of renewable diesel refining, can act as a one-to-one substitute for fossil naphtha in steam cracking processes[lix]. This is a highly attractive option for companies because it does not require investment in new equipment, and major chemical producers such as BASF and LyondellBasell are already marketing products which replace a portion of fossil naphtha with bio-based feedstocks[lx].

Figure 4: Simplified diagram of steam cracking route to olefins and aromatics



Steam cracking has the technical potential, under specific conditions, to be emissions-neutral by 2050. However, heavy dependence on this route could put pressure on sustainable biomass supply. The steam cracking process would be emissions-neutral only if the heat source were electrified and powered by renewable energy, if 100 per cent emissions-neutral feedstock were used, and if all gas by-products of the process were captured. A major drawback of steam cracking, however, is that it is compatible only with a very narrow range of non-fossil feedstocks: bionaphtha and a feedstock called 'pyrolysis oil' derived from chemically recycled plastic waste (pyrolysis is covered in depth in our 2022 briefing, *Coming around: How chemical companies must adapt to the circular economy*). Steam crackers also require very large volumes of feedstock to operate economically[lxi]. Widespread reliance on bionaphtha steam cracking could therefore put high pressure on supplies of sustainable biomass. Plastic waste will also be a limited resource in the future, and due to the low quality of pyrolysis oil it may not be possible to operate steam crackers on this feedstock alone[8]. In practice, therefore, steam cracking using plastic waste would likely still require heavy dependence either on fossil fuels or on bioresources.

Steam cracking is unlikely to be sustainable in the long term, so alternative routes to HVC production should be favoured. The alternative to steam cracking is to make olefins and aromatics from methanol, via the methanol-to-olefins (MTO) and methanol-to-aromatics (MTA) processes, as described in our 2021 briefing[lxii]. Methanol can be made with a wider variety of non-fossil feedstocks, including renewable hydrogen and captured carbon as well as biomass and plastic waste, thereby mitigating dependence on any single feedstock type. Companies should therefore favour investments in renewable methanol production and MTO/MTA over investments in steam cracking[9].

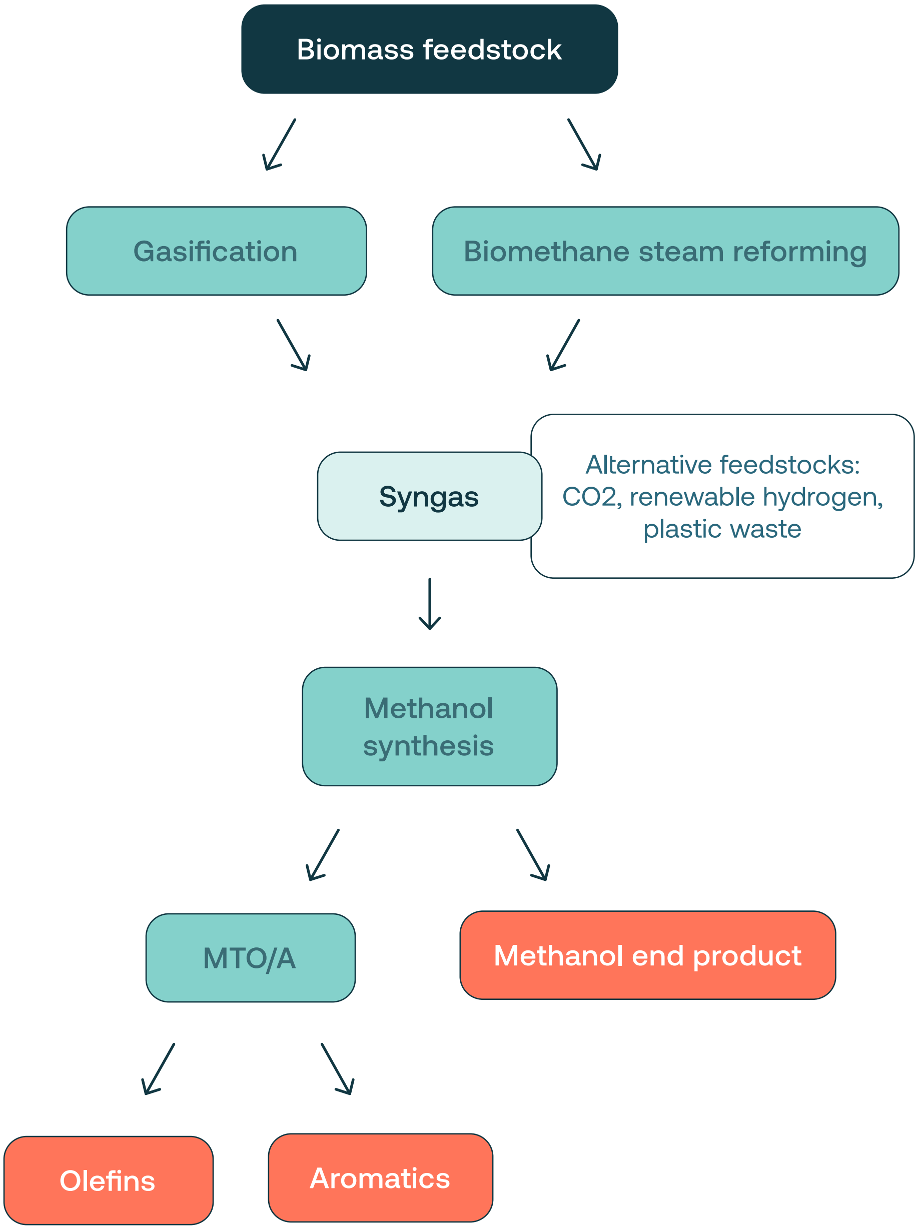
Syngas-based methanol and HVC production: A small amount of biomass can be adopted alongside other emissions-neutral feedstocks

Another way of producing primary chemicals from bio-based feedstocks is to use biomass to generate 'syngas', a mixture of carbon dioxide, carbon monoxide, and hydrogen molecules[lxiii]. Syngas can then be converted to methanol using conventional methods, and methanol can subsequently be used to produce HVCs[lxiv].

8 See: Martin Kusenberg et al. (2022), 'Opportunities and challenges for the application of post-consumer plastic waste pyrolysis oils as steam cracker feedstocks: To decontaminate or not to decontaminate?'. *Waste Management* 138: 83-115, p. 106. Available online at https://www.sciencedirect.com/science/article/pii/S0956053X21005894 [accessed 04 April 2023].

9 Recent modelling conducted by the consultancy SYSTEMIQ suggests that, in a high-ambition scenario, aromatics production from MTA could outstrip that from cracking by 2050. MTO constitutes a smaller but still important route for olefin production in the same high-ambition pathway (26% of total production). SYSTEMIQ (2022). *Planet-Positive Chemicals: Pathways for the chemical industry to enable a sustainable global economy*, pp. 52-57. Available online at: https://www.systemiq.earth/wp-content/uploads/2022/10/Main-report-v1.22.pdf [accessed 08 March 2023].

Figure 5: Simplified diagram of syngas routes to methanol, olefins, and aromatics



Because syngas can be produced using a variety of non-fossil feedstocks, including captured carbon and renewable hydrogen as well as biomass and plastic waste, methanol and HVC production based on syngas does not have to lock in long-term dependence on bioresources. For this reason, biomass-based syngas production could sustainably play a small role in primary chemical production in 2050, but bio-based feedstocks will need to be adopted alongside other emissions-neutral feedstocks.

Syngas can be produced from biomass in two ways: biomethane steam reforming and gasification.

Biomethane steam reforming

Methane steam reforming is widely used today as a means of producing syngas from natural gas. In this process, natural gas (methane) reacts with steam under conditions of high temperature and pressure to form syngas. The syngas then needs to be upgraded by removing CO_2 before being fed into a methanol converter[lxv].

In the bio-based route, natural gas is replaced by a biofuel called biomethane, which is chemically very similar to natural gas[lxvi] and can act as a direct substitute for it[lxvii]. Biomethane is a derivative of biogas, which in turn is a product of the digestion of biomass by microbes in an oxygen-free environment (a process called 'anaerobic digestion')[lxviii]. Biogas is already commercially available, particularly in Europe[lxix], and can be produced from a variety of kinds of solid biomass, including waste streams such as household organic waste, sewage sludge, and manure[lxx].

In order to be close to emissions-neutral, biomethane steam reforming would need to meet the following conditions:

1. Steam generation would need to be electrified and powered by 100 per cent renewable energy.
2. Any excess CO_2 produced during the upgrading of biogas feedstocks and the upgrading of 'raw' syngas would need to be supplemented with green hydrogen and recycled in the methanol synthesis process to eliminate direct emissions[lxxi].
3. Biogas would need to be produced from waste sources only[lxxii].

Gasification

Syngas can also be produced through a process called gasification, which heats biomass feedstocks to high temperatures (800–1500C) in the presence of limited oxygen[lxxiii]. This syngas needs to be cleaned to remove impurities and then upgraded to adjust the carbon monoxide to hydrogen ratio, which can be done either by removing CO_2 or adding hydrogen[lxxiv]. The syngas can then be converted to methanol.

A wide variety of virgin and waste biomass feedstocks can undergo gasification, including forestry biomass, processing wastes from the pulp and paper industry, the organic portion of municipal solid waste, agricultural residues, and second-generation energy crops[lxxv].

Gasification would need to meet strict conditions in order to be close to emissions-neutral:

1. Gasifiers would need to be electrified and run on 100 per cent renewable energy.
2. The processing of biomass feedstocks prior to gasification, such as drying and sizing, would need to be electrified and run on 100 per cent renewable energy.

3 Excess CO_2 contained in the syngas would need to be supplemented with green hydrogen and recycled in the methanol synthesis process.

Companies must take steps now to limit long-term dependence on biomass

When processed using syngas routes, biomass may provide one platform among others for methanol and HVC production. However, companies must develop a broader strategy to reduce and ultimately eliminate dependence on bioresources. The following section will describe what steps chemical companies can take now to ensure their use of bioresources remains within sustainable limits.

Part 3:

Three actions chemical companies can take to minimise exposure to biomass risks

Part 3: Three actions chemical companies can take to minimise exposure to biomass risks

While biomass can play a very small role in the transition to emissions-neutral methanol and HVC production, companies must acknowledge the limitations and risks of biomass use in every aspect of their short- and long-term strategy. In this section, we recommend several actions they should take in order to avoid unsustainable dependence on bioresources.

1 Minimise demand for biomass now

Chemical companies must take steps now to ensure that the sector's use of biomass does not exceed sustainable limits.

First, companies must support the transition to the circular economy. By supporting demand reduction for primary chemicals at a system level, companies can help to reduce feedstock demand pressures. They must therefore ensure that the products they manufacture do not contain hazardous chemicals and can be easily reused and recycled. This is explored in further detail in our 2022 briefing, *Coming around: How chemical companies must adapt to the circular economy*.

Second, companies must favour investments in non-biobased alternatives to fossil fuels, prioritising captured carbon and renewable hydrogen. Methanol producers should begin piloting and scaling end-to-end production processes based on captured carbon and renewable hydrogen as soon as possible. HVC producers should favour investments in methanol-based routes for olefins and aromatics, which can integrate with captured carbon and renewable hydrogen feedstocks.

Companies must therefore:

- Commit to phasing out hazardous chemicals from their products, and set out a plan to do so;
- Favour investments in non-bio-based feedstocks, particularly captured carbon and renewable hydrogen; and
- Favour investments in methanol-based routes for HVC production, which can integrate with a wider variety of alternative feedstocks.

Companies must disclose a long-term strategy, with intermediate targets, to phase in non-fossil-based feedstocks that are emissions-neutral over their entire lifecycle, with the aim of transitioning to 100 per cent emissions-neutral feedstocks by 2050.

2 Source biomass in line with strict sustainability criteria

Any biomass that companies do source for feedstock purposes must meet strict sustainability criteria. Companies must source their biomass feedstocks according to the principles set out earlier in this briefing, and should engage with suppliers continuously and in detail in order to ensure that their feedstocks are being produced according to the highest possible standard of sustainability. **Certification should not be considered adequate to verify the sustainability of biomass feedstocks.** Supply chains should be traceable across the entire lifecycle, and companies should publicly disclose their supply chains as well as the sustainability criteria they use in their sourcing.

Companies must therefore:

- Publicly disclose a detailed procurement policy for their biomass feedstocks, laying out, in full, minimum sustainability criteria, verification and monitoring arrangements, and the entire supply chain for all biomass sourced.

3 Develop and implement a strategy to reduce long-term demand for biomass

Biomass is not a permanent solution for the sector, and chemical companies need to reflect this in their short-, medium-, and long-term planning. Modelling conducted by the consultancy SYSTEMIQ suggests that, even in a high-ambition scenario in which fossil fuel use declines steeply, biomass need not account for more than 43 per cent of feedstock demand in the global chemical sector by 2050[lxxvi] – and every effort should be taken to reduce this amount even further. To enable a low-biomass future, chemical producers must take initiative now to develop detailed strategies minimising their long-term dependence on biomass.

Companies must therefore:

- Acknowledge in strategies and public communications that biomass is not a final solution for the chemical sector's feedstock needs;
- Set out clearly how non-biomass alternative feedstocks will increase as a proportion of the overall alternative feedstock mix over time; and
- Set out clearly how methanol-based routes to HVC production can scale over time.

Engagement questions

Engagement questions

Investors can use their influence to encourage investee companies to take the actions recommended here.

We set out below a series of questions to guide investors in their engagements with chemical companies. We also provide outcomes that investors can use to track company performance and the success of engagements over time.

Because of the lack of adequate mechanisms for monitoring and enforcing the sustainability of biomass supply chains, investors may not be able to verify the answers to all of these questions, and even chemical companies themselves may be unable to answer them with a high degree of confidence. The questions marked with an asterisk are particularly hard to verify – investors should treat answers to these with caution and close scrutiny.

Bioenergy use

1 Has the company committed to excluding the use of biomass for direct or indirect energy generation beyond 2050, and to phasing out any current use by 2050 at the latest?

- *Tracking outcome:* The company has committed to excluding the use of biomass for direct or indirect energy generation beyond 2050, and has a plan to phase out current use of biomass for direct or indirect energy generation by 2050 at the latest.

Emissions-neutral feedstock strategy

1 Has the company committed to transition to 100 per cent emissions-neutral feedstocks and production processes by 2050 at the latest?

- *Tracking outcome:* The company has set out plans for the short, medium, and long term, with intermediate targets, to:

    - phase in electrified chemical processes, with the aim of transitioning to 100 per cent electrified processes by 2050;
    - increase energy consumption from renewable energy sources, with the aim of reaching 100 per cent renewable energy by 2050; and
    - phase in non-fossil-based feedstocks that are emissions-neutral over their entire lifecycle, with the aim of transitioning to 100 per cent emissions-neutral feedstocks by 2050.

If the company uses biomass as a feedstock:

2 How does the company justify using biomass, rather than alternative feedstocks such as renewable hydrogen or air- or point-source captured carbon?

- *Tracking outcome:* The company can explain its rationale for resorting to bio-based feedstocks over other available alternatives.

3 How will the company increase its use of alternative feedstocks, such as renewable hydrogen or air- or point-source captured carbon, and reduce its biomass use over time?

- *Tracking outcome:* The company has a detailed strategy to phase in non-fossil-based, non-biomass feedstocks.

Investments in bio-based chemical production

1 If the company plans to invest in gasification assets, how will it ensure that gasification is close to zero emissions?

- *Tracking outcomes*:
  - Gasification plants owned or financed by the company that will become operational after 2025 will:
    - use electrified external heat sources and have a plan to source 100 per cent renewable energy by 2050; and
    - use renewable hydrogen to upgrade 'raw' syngas (thereby eliminating CO_2 emissions at this stage)
  - Any syngas from biomass used in production processes is from plants that will be compliant with these conditions by 2050 at the latest.

2 If the company is planning to use methane steam reforming to produce methanol from biogas, does it have a plan to ensure that the process is close to zero emissions?

- *Tracking outcomes*:
  - Methane steam reforming assets owned or financed by the company that will become operational after 2025 will:
    - use electrified heat sources and have a plan to source 100 per cent renewable energy by 2050;
    - use biogas derived from 100 per cent waste sources;

  - recycle all CO_2 produced during biogas upgrading and syngas upgrading in the methanol synthesis process; and
  - use renewable hydrogen to upgrade raw syngas.
- Any syngas from biomethane steam reforming used in production processes is from plants that will be compliant with these conditions by 2050 at the latest.

Sustainability criteria for bio-based feedstocks

Transparency and traceability

1 Are all biomass feedstocks traceable across their entire supply chains? Has the company publicly disclosed their supply chains?

▸ *Tracking outcome:* The company has verified that its biomass feedstocks are traceable across their entire supply chains. It has disclosed publicly the entire supply chain for all of its feedstocks.

2 Has the company committed to disclosing emissions across the whole lifecycle of all bio-based products, including:

- supply chain emissions, including:
  - changes in above- and below-ground carbon stock due to land-use change;
  - changes in above- and below-ground carbon stock due to land management practices;*
  - emissions associated with cultivation, harvesting, processing, and transportation processes;* and
- direct emissions from chemical production processes?

▸ *Tracking outcome:* The company has committed to monitor and disclose emissions across the whole lifecycle of all bio-based products, including emissions from chemical production processes and feedstock lifecycle emissions as detailed above.

3 Does the company require its suppliers to be audited by independent third parties? Does it require field inspections of sourcing areas as well as desk-based audits?

▸ *Tracking outcome:* The company requires its suppliers to be audited by independent third parties, and field inspections of sourcing areas are required in addition to desk-based audits.

Supply chain emissions

1 Can the company verify that no biomass harvesting or cultivation has occurred in lands with high carbon stocks, including natural forests, peatlands, and natural grasslands; or on any lands which have recently been converted from such uses?

- *Tracking outcome:* The company can demonstrate that no harvesting or cultivation has occurred in lands with high carbon stocks, or on lands that have recently been converted from such uses.

2 Can the company verify that above- and below-ground carbon stocks at the sourcing area level are being maintained or increased over short timescales?*

- *Tracking outcome:* The company can provide evidence that above- and below-ground carbon stocks at the sourcing area level are being maintained or increased over short timescales.

3 Does the company engage with feedstock suppliers to align emissions from the cultivation, harvesting, processing, and transportation of biomass feedstocks with 1.5C low/no overshoot pathways?

- *Tracking outcome:* The company can demonstrate that it engages with feedstock suppliers to align emissions from the cultivation, harvesting, processing, and transportation of biomass feedstocks with 1.5C low/no overshoot pathways, including by electrifying equipment and using 100 per cent renewable energy for energy needs, as well as by minimising the use of nitrogen-based fertilisers.

Biodiversity and wider ecosystem impacts

1 Can the company verify that no biomass harvesting or cultivation has occurred in areas of high biodiversity importance, including any highly biodiverse forests, wetlands, and grasslands, or in any preserved natural ecosystems; or on lands that have recently been converted from areas of high biodiversity importance?

- *Tracking outcome:* The company can demonstrate that no harvesting or cultivation has occurred in areas of high biodiversity importance, or on lands that have recently been converted from areas of high biodiversity importance.

2 For all biomass feedstocks, has the company verified:

  - that suppliers minimise the use of synthetic pesticides, herbicides, and fertilisers in biomass cultivation;*

- that suppliers avoid the introduction of species which have a high risk of becoming invasive;*
- that demand for groundwater does not exceed supply, and that water is not diverted from higher priority uses, e.g. drinking water or agriculture;* and
- that biomass suppliers monitor soil health, and take all available measures to prevent erosion and to maintain or improve soil nutrient content?*

▶ *Tracking outcome:* The company sources feedstocks exclusively from suppliers that can provide evidence that they comply with these conditions.

Feedstock-specific criteria

1 Does the company implement a circular economy approach to the use of biomass feedstocks, prioritising industrial and municipal waste sources of biomass over virgin materials?

▶ *Tracking outcome:* The company demonstrates that it has identified all available organic waste streams for biomass use, and uses these before deploying feedstocks from virgin biomass.

2 Where the company is using feedstocks derived from energy crops:

- does it commit not to source such feedstocks from 'first-generation', i.e. food and feed, energy crops?
- has it verified that biomass cultivation has occurred exclusively on marginal or degraded land, which cannot be used for food production and is not suitable for nature restoration or alternative forms of climate mitigation, e.g. afforestation?*

▶ *Tracking outcome:* Where the company is using feedstocks derived from energy crops, it commits to using 100 per cent second-generation energy crops, and to excluding the use of food and feed energy crops. It can also provide evidence that feedstocks have been harvested exclusively on marginal or degraded land.

3 Where the company uses forestry biomass as feedstocks, can it verify:

- that harvesting has occurred exclusively in existing forests managed for industrial timber which follow the principles of sustainable forestry[10];

10 For example, as defined by Forest Europe; see Third Ministerial Conference on the Protection of Forests in Europe (1998), 'ANNEX 2 OF THE RESOLUTION L2: Pan-European Operational Level Guidelines for Sustainable Forest Management', available online at https://foresteurope.org/wp-content/uploads/2016/10/MC_lisbon_resolutionL2_with_annexes.pdf#page=18 [accessed 31 March 2023].

- that feedstocks are exclusively derived from industry wastes and forestry residues which have short carbon payback periods and cannot be put to higher-priority materials uses;*
- that suppliers are respecting species-specific regrowth periods;*
- that suppliers are appropriately managing biodiversity risks, for example by planting diverse and, where possible, native tree species, avoiding overextraction of residues, and excluding significant portions of land within management area (e.g. 25 per cent) from harvesting?*

▸ *Tracking outcome:* The company sources forestry feedstocks exclusively from suppliers that comply with these conditions.

4 Where the company uses forestry biomass as feedstocks, can it verify:

- that residues have not been diverted from higher-priority materials uses, e.g. animal bedding?*
- that an adequate amount of residues have been left in the ground to protect soil health (precise amount dependent on location)?*

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Registered Charity Number: 1117244

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