# Biomass in a Low-Carbon Economy: Resource Scarcity, Climate Change, and Business in a Finite World

## Key Findings

- **Biomass is not a 'silver bullet' solution to the climate challenge, but it is a promising source of low-carbon energy that could help reduce emissions, along with other renewable resources; energy efficiency gains; behavioural changes; and changes in policies, industrial practices, and human settlement patterns.**
- **Biomass production is constrained by land and water availability, by soils' ability to produce biomass, and by the need to return some biomass to the land to retain nutrients and soil moisture, as well as by competing uses and by the need to reduce emissions from land conversion and agriculture.**
- **We explored four scenarios: a 'Single Bottom Line' focused on maximising economic profits; 'Meeting the Climate Challenge', focused entirely on curbing emissions; 'Feeding the Planet', focused on increasing food production; and a 'Sustainability Transition' that uses biomass for food, energy, industrial materials, and more. Our analysis shows the latter could yield great benefits, helping address the urgent climate problem while spurring improvements in agriculture to boost food production and result in new agricultural products. The transition could also spur business innovation and economic growth.**
- **There is a significant need for focused agricultural research to further boost yield potential, shed light on the reasons for yield gaps, and greatly narrow those gaps. Research is needed on both genetic modifications, and potential improvements through conventional breeding techniques. There is also a need to further explore the human, social, legal, and political factors that affect agricultural production.**

### Biomass and the low-carbon economy

Building a low-carbon economy and reducing greenhouse gas emissions to keep climate change within relatively safe bounds will require increasing use of biomass – mostly from plants.

Biomass is a promising source of renewable low-carbon energy, but it's not an unlimited resource: it is constrained by land and water availability, by soils' ability to produce biomass, and by the need to return some biomass to the land to retain nutrients and soil moisture. There are also competing uses for biomass: for food, for animal feed, for materials – and the need to reduce emissions constrains not only energy supplies, but also land conversion and agricultural practices. Finally, biomass is needed for natural habitat and ecosystem functioning, all the more important as ecosystems are threatened by a changing climate.

In this context, biomass is hardly a "silver bullet" – but it can be part of the solution to the low-carbon energy challenge, along with other renewable resources; greater energy efficiency; behavioural changes; and policies, industrial practices, and human settlement patterns that lead to lower carbon emissions.

Currently, the discussion of biomass resources in a low-carbon world is dominated by existing energy uses – that is, for combustion and as feedstock for biofuels. In the long run, however, increasing electrification and new technologies could significantly reduce demand for biofuels and other liquid fuels. As this occurs, a new "bio-based economy" may emerge that focuses less on low-carbon energy and more on meeting demands from industry: for feedstocks for the production of chemicals and materials, and for combustibles for process heat. In an increasingly resource-constrained world, innovation and novelty in industrial biomass uses could spur continued economic growth.

This policy brief, based on a report produced through a partnership between the business leaders' initiative 3C (Combat Climate Change) and the Stockholm Environment Institute,

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**Box 1:** **The four scenarios**

**Single Bottom Line:**
A world in which the main focus is on growth as usual, an economic "single bottom line". There is little attention paid to climate beyond the policies currently in the pipeline, and little interest in making agriculture more productive or sustainable.

**Meeting the Climate Challenge:**
The world adopts strong climate policies and pursues multiple options to reduce carbon emissions, including greater energy efficiency and switching to low-carbon fuels and processes. Biofuels play a prominent role, and biofuel markets drive investment and productivity improvements in agriculture, with few policy interventions.

**Feeding the Planet:**
World leaders cannot agree on strong climate policies and make only scattered efforts beyond the policies already in the pipeline. However, public and private actors do focus intensely on feeding the world and follow diverse avenues to try to boost agricultural yields without seriously damaging ecosystems.

**Sustainability Transition:**
People worldwide frame their future in terms of sustainability, and see the pursuit of a bio-based economy as one way to achieve this. There is a strong policy push towards limiting human impacts on the climate while also developing a high-yielding but sustainable agriculture. Only the first steps can be taken in the relatively short time of the scenario, but by 2035, it is clear that a sustainability transition is possible.

seeks to envision the contribution of a bio-based economy to a low-carbon economy between now and 2035. There are multiple uncertainties, many linked to human choices – specifically, whether to act aggressively to mitigate and adapt to climate impacts, and whether to increase agricultural production. We consider four scenarios, which are defined by the strength of the policy focus on climate, agriculture, or both (see Box 1).

Avoiding dangerous climate change is possible, though challenging. McKinsey & Company's abatement cost curves show nearly one-third of total mitigation potential by 2030 would be in forestry and agriculture, with further potential from biomass in other sectors – for biofuels (in transport) and biopower (in the electric sector). These reductions can be realised through a combination of a carbon price, minimum energy and carbon efficiency standards, and an international effort to reduce emissions from forestry and agriculture, combined with public support for specific low-emitting technologies, to help bring down costs.

## The bio-based economy

We are surrounded by remarkable – and unique – chemical factories. The photosynthesis carried out by plants is the only process known to break the chemical bonds in carbon dioxide at ordinary temperatures and pressures. Once the bonds are broken, plants construct complex carbon compounds with stable, high-energy bonds. Then they, and other living things, use those compounds for energy, nutrients, and structural materials. Indeed, all of the complex carbon compounds in today's economy, including fossil carbon, are ultimately derived from a product of photosynthesis, whether directly, as with wheat grain, cotton fibre, and palm oil, or indirectly, as with cellophane, gasoline, and synthetic plastics.

In a bio-based economy, currently petroleum-derived materials, such as transportation fuels and plastics, are replaced by materials derived from biological carbon sources. In addition, technologies requiring rare mineral resources may be partially replaced by carbon-based materials such as organic conductors.

It must be stressed that simply using biomass as a source does not guarantee net zero or negative greenhouse gas emissions, and the low-carbon economy constrains biomass production to certain types of land conversion and certain agricultural practices. If land with high carbon density is converted to biomass production at a lower carbon density, there will be a one-time release of carbon when the land is cleared and replanted. Also, some agricultural inputs emit greenhouse gases when they are produced, and some agricultural practices result in emissions of nitrous oxide or methane, both potent greenhouse gases.

## Limits to biomass production

Biomass is a renewable, but limited resource. Like surface water, it regenerates naturally, but at any given moment only a finite amount is available. Also like water, the resource can become degraded through human action. Estimates of bioenergy potential are highly variable. One recent analysis assessed 19 studies of long-term prospects for of bioenergy production worldwide, and found an enormous diversity of estimates, ranging from zero to 1,548 exajoule per year (more than three times today's global primary energy supply). Within this broad range, half the estimates fell between 162 and 297 exajoule per year in 2050, which is between 33 and 60 per cent of current global energy consumption. However, sustainability constraints shift the estimate towards the lower end of this range.

The main determinant of energy crop estimates is the available land, which is sensitive to assumptions about population growth, diet (especially meat consumption), and crop yield improvements. In addition, other factors unrelated to bioenergy potential may play critical roles, such as competition between energy feedstocks and food production, and political, economic and cultural dynamics. Figure 1 illustrates the inputs to, and uses of, biomass.

## Boosting production

The potential to improve crop yields may be limited, and yield increases have slowed and plateaued in many countries in recent years. Broadly, strategies focus both on increasing the yield potential – yield under ideal conditions, with no limits on water or nutrients, and effective control of pests, disease, or other stresses – and shrinking the gap between potential and actual yields.

The dramatic increases in yields of wheat, barley, and rice, three major "Green Revolution" crops, were mainly the result of shifting plant biomass to the grain rather than to stems and leaves – a strategy that favours food production but doesn't increase total biomass production. Some countries have very low yields compared to potential. Where yields are already high, light utilisation (photosynthesis) is seen as the most promising target for breeding and genetic modification to further increase yield

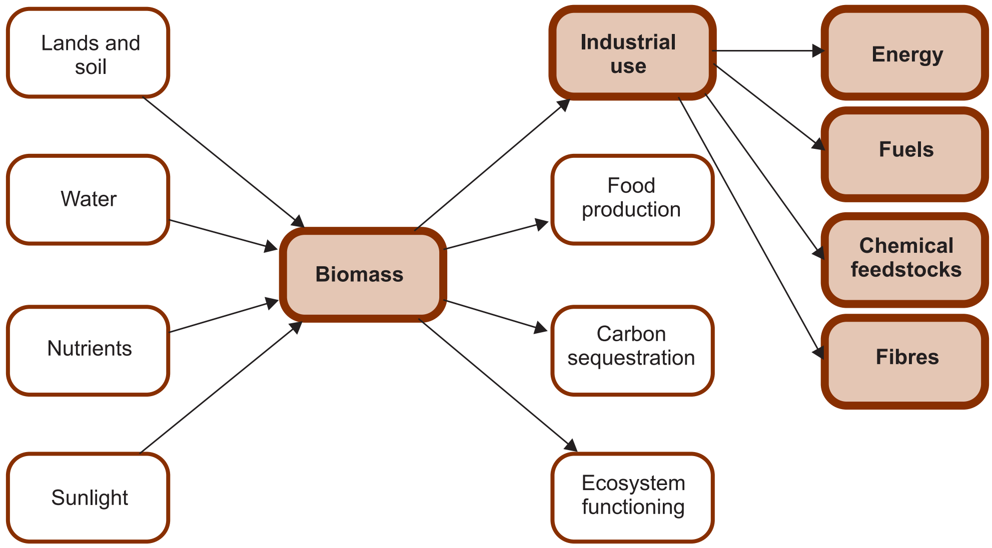


**Figure 1: Biomass in the economy**

potential. Some have estimated that with an active research programme, plants with up to 20 per cent higher photosynthetic efficiency could be in farmers' fields within 25 years.

Still, soils, climate, and slope may not be ideal for a given crop, and farmers always face economic constraints, so realised yields will never fully match yield potential, even if all other stresses – such as pests and diseases – are effectively controlled. In most of our scenarios, more land is needed, and as FAO estimates suggest that highly productive land is already occupied, any expansion will be onto less productive land.

## Scenario outcomes

The Meeting the Climate Challenge scenario keeps cumulative emissions to 1,000 Gt $CO_2$ by 2035, but requires either zero annual emissions from 2036 onward, or net negative emissions later in the century. In contrast, the Sustainability Transition scenario seeks to meet climate mitigation targets soon, sharply reducing annual emissions by 2020 using more biomass for energy (25 per cent of the total supply in 2035, versus 13 per cent under Meeting the Climate Challenge). Nevertheless, total demand for biomass is not much greater, kept in check by a combination of low total energy consumption and lower meat consumption. As shown in Figure 2, food consumption dominates human use of biomass in all scenarios, but biomass use for both energy and chemicals increases.

In terms of agricultural land use, three of the four scenarios lead to similar increases. However, in the Sustainability Transition, that is partly because some productive agricultural land is given up to restore ecosystems, and some potential yield increases are sacrificed for a smaller environmental impact. At the same time, the Sustainability Transition helps meet the climate challenge through carbon sequestration and by supplying feedstock for biofuels and combustible material for electricity and heat production. In contrast, the Feeding the Planet scenario only seeks to improve agricultural output while lessening agriculture's

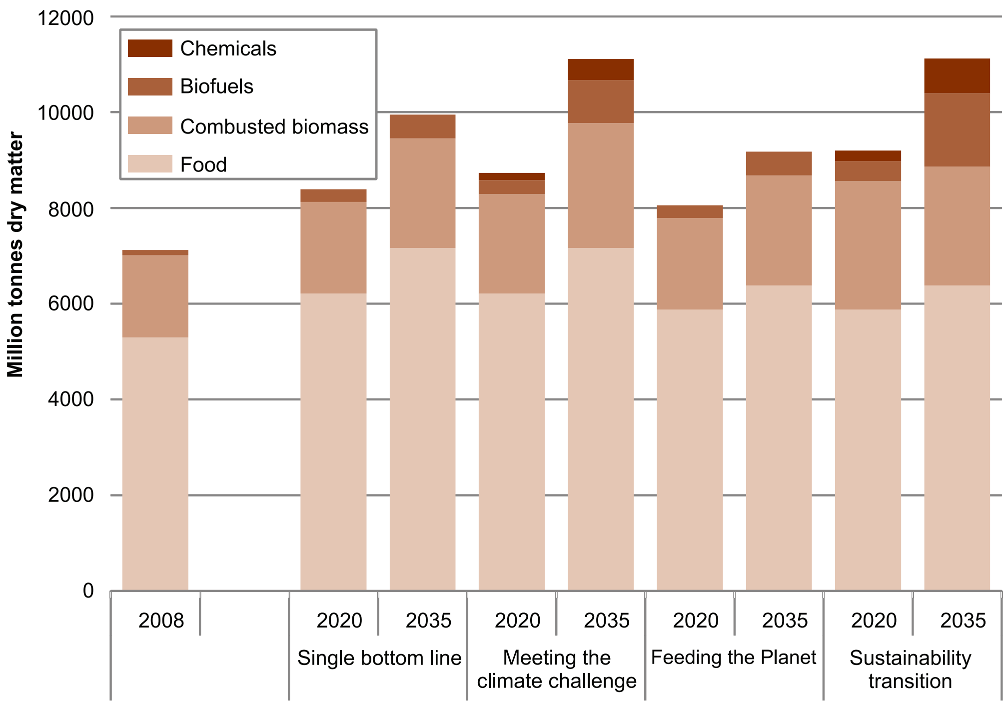


**Figure 2: Use of biomass in the scenarios**

impact, which leads to a strong reduction in agricultural footprint. In the Meeting the Climate Challenge scenario, the world reduces carbon emissions, but humanity's agricultural footprint increases through moderate increases in biofuels production and much more significant increases in food production with only modest increases in yields. The Single Bottom Line scenario, while perhaps most aligned with current political realities, may ultimately undermine itself, as it would push resource consumption beyond the physical boundaries of the earth's safe operating space.

Our analysis suggests that while no one path is perfect – and most would increase pressure on the land – a "Sustainability Transition", combining a focus on both agricultural production and climate mitigation, could yield benefits on both fronts. It could also spur innovation – if we encourage the use of bio-materials, then entrepreneurs and businesses can take this on as a challenge, and thrive on it. And in the long run, we will be building a solid and sustainable foundation for our future economy.

This policy brief is based on an SEI report with the same title, by Eric Kemp-Benedict, Sivan Kartha and Amanda Fencl, which is available on our website. This research has been carried out within the partnership programme between the Stockholm Environment Institute and the business leaders' initiative 3C (Combat Climate Change).

**Policy considerations**

- Both the size of the biomass resource and the structure of future demands are highly uncertain, and they will be shaped to a great extent by policy choices and priorities. All the scenarios we explored have trade-offs, and none reduces the footprints of both agriculture and carbon emissions. However, of them all, the Sustainability Transition shows the most positive results, with the greatest climate benefits as well as improvements in agriculture that boost food production and yield new agricultural products.
- Boosting the use of biomass for energy as part of a strong near-term climate strategy will increase pressure on stressed resources, but is also likely to spur innovation and could help industry shift away from depletable fossil resources, and towards biomass-based feedstocks. This could help build a bio-based economy and provide a sustainable path to long-term prosperity.
- It is important to remember that in our current political and economic systems, the allocation of resources is driven primarily by effective demand, rather than human needs. Thus, as we noted in the context of food, people in rich countries consume more than is healthy, while others go hungry. For the bio-based economy, this means in the short term, development is likely to be driven by demand from wealthier "eco-conscious" consumers. Eventually, however, it is important to ensure that products are affordable and accessible to all, while keeping resource use within critical thresholds.
- The development of a bio-based economy faces coordination problems, so if it is to emerge, it is essential to build a market for biomass-based products. Companies can close the gap by finding a niche within the value chain. If the public sector encourages the use of bio-materials through research and development investment and purchasing, businesses can take this on as a challenge, and thrive on it.
- The world needs a major, focused agricultural research programme involving both the public and private sectors. Returns on agricultural investment in both sectors are high, around 20-30 per cent, with a payoff period of 8-15 years in the private sector and 15-25 years in the public sector. This suggests that public funds should support long-term, fundamental research, and private funds should translate the gains from that research into practical applications.
- Most of the research would focus on raising yield potential and closing yield gaps, but it should also seek to better understand the people who produce the crops, and how livelihoods and social and institutional dynamics affect yields. With the right incentives, agronomic research might also deliver on the promise of genetically modified crops targeted to the needs of farmers in poor countries, such as drought-tolerant crops. However, given continuing uncertainty over the environmental impacts of genetically modified organisms and the slow progress on genetic modifications, it is crucial to also pursue improvements through conventional breeding techniques.

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