

On the science of carbon debt

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Summary and key Drax take-aways undertaken by:

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Strengers, B., Matthews, R., Berndes, G., Cowie, A., & Laganière, J. (2024). On the Science of Carbon Debt. PBL Netherlands Environmental Assessment Agency. ~300 pp.

Summary

PBL's On the Science of Carbon Debt (Strengers et al., 2024) is a comprehensive, science-based guide clarifying the nuanced impacts of forest biomass use. It emphasises that outcomes vary significantly, depending on management, usage patterns, and methods. It urges policies and analyses to explicitly recognise carbon debt, rigorously evaluate scientific studies, and align CO₂ assessments with wider sustainability frameworks. The report combines conceptual narrative with technical foundations, offering actionable recommendations for policymaking.

Drax was not involved in the production of the report.

Key Drax take-aways

Key ideas and recommendations in the report that are relevant for informing Drax' approach to evaluating and monitoring carbon stocks and avoiding carbon debt in its biomass sourcing areas are outlined below. These are grouped into two main messages:

1. Careful attention to assessing and monitoring harvesting levels in our source regions; and the type/source of biomass sourced can avoid or minimise carbon debt.
 - Stable or slowly increasing harvest levels are critical to maintaining carbon stocks.
 - Exceptions apply for salvage logging and resilience-focused management that help reduce the risk of climate loss from climate change or natural disturbances.
 - Increasing harvest intensity in existing forests—more frequent or heavier thinning, or more frequent clearcuts – causes the greatest risk of carbon debt.
 - Low-risk feedstocks include residues or salvage material that would otherwise be burned in situ.
2. There are several approaches that can be used to evaluate and monitor carbon stocks; and the following are important for Drax.
 - Regional-scale assessment, for instance the sourcing area around a pellet mill, is the appropriate level to evaluate forest carbon stocks for a biomass user that doesn't manage its own forest.
 - Consistent, long-term data collection is essential for credible carbon stock assessments.
 - Developing and incentivising practical, on-the-ground forest management that supports both carbon sequestration and sustainable biomass supply is a key opportunity for forest operators.
 - Monitoring is essential to confirm that management plans are implemented.
 - Ongoing monitoring should also verify changes in carbon stocks are similar to expected changes based on historic forest characteristics and natural disturbances.

Extended summary

Clarifying the concept of “carbon debt”

The report provides a detailed explanation of carbon debt - an increase in atmospheric CO₂ that can occur when forest biomass is harvested and used for energy. It explains that using forest biomass for energy can result in a temporary spike in CO₂ emissions (a “carbon debt”), that can be repaid over time as forests regrow and reabsorb carbon, and as avoided GHG emissions accrue due to fossil fuel substitution. The scale and duration of repayment depends on forest type, management, and biomass end-use.

Rather than categorising forest biomass as inherently “carbon neutral” or universally worse than fossil fuels, the report stresses that outcomes are context-dependent. Even biomass from well-managed forests can result in net emissions if used inappropriately or at unsustainable scales. Conversely, under the right conditions, forest bioenergy can support emissions reductions. The report argues that sweeping generalisations fail to reflect the complexity of carbon flows in forest systems and energy use.

Using a range of case studies and scenarios, the report illustrates that biomass use can have widely varying climate outcomes. In some situations, it leads to high emissions and long payback periods, for example when whole trees are harvested intensively (e.g. clear-cutting). In others—such as when using mill residues, salvage wood, or thinning by-products—biomass can deliver near-immediate or even net-negative emissions outcomes. These divergent results underscore the need for careful supply chain evaluation and tailored sustainability criteria.

Diversity in scientific methods

A central message of the report is that different studies on biomass and carbon debt often reach conflicting conclusions because they use different assumptions, scales, and system boundaries. Forest type, management practices, energy conversion efficiency, and carbon accounting frames can all heavily influence results. Therefore, the report warns against cherry-picking studies to support a fixed narrative and instead calls for critical, methodologically informed interpretation of the evidence base.

Policy implications

The report includes a dedicated chapter translating its scientific findings into practical implications for biomass policy. It outlines how policymakers can design regulations and incentives that recognise the risk of carbon debt while also accounting for the potential benefits of well-managed biomass systems. By using more sophisticated carbon accounting and lifecycle analysis tools, policies can better distinguish between high- and low-risk biomass sources. The report also encourages alignment with broader climate and land-use goals, ensuring that biomass use supports long-term decarbonisation strategies.

Technical depth and transparency

Supporting the report’s main conclusions is a robust technical foundation, including five appendices that delve into modelling methods, carbon accounting frameworks, and data interpretation. These technical sections are designed to be accessible to researchers, auditors, and policymakers alike, allowing users to scrutinise assumptions and replicate approaches. The report’s emphasis on transparency and methodological rigour reinforces its role as a trusted reference for decision-makers working at the intersection of climate policy, forestry, and bioenergy.

Recommendations for policymakers

The report outlines six main recommendations for policymakers:

1. Acknowledge carbon debt risk in policies on biomass supply and use, while considering neutrality and synergy potentials.
2. Exercise caution in using published studies, developing critical evaluative tests regarding their policy relevance and methods.
3. Avoid simplistic claims about biomass' climate impact—communications should reflect complexity and uncertainty.
4. Benchmark existing sustainability criteria against improved methods proposed in the report to identify gaps.
5. Further develop and test these technical methods, enhancing frameworks to ensure biomass supports emissions goals.
6. Integrate biogenic carbon assessment with broader sustainability frameworks, clarifying overlaps and distinctions.