Policy brief

Bioenergy policy

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# State of global land regulation inadequate to control biofuel land-use-change emissions

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Under current land-use regulation, carbon dioxide emissions from biofuel production exceed those from fossil diesel combustion. Therefore, international agreements need to ensure the effective and globally comprehensive protection of natural land before modern bioenergy can effectively contribute to achieving carbon neutrality.

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## The policy problem

Large fractions of the global forest and natural land cover are not effectively protected. If bioenergy cultivation is not strictly limited to marginal or abandoned land, bioenergy may be grown on agricultural land and displace food production. Shifting food production elsewhere can cause substantial carbon dioxide ($CO_2$) emissions due to forest clearing in regions with weak or no land regulation. This puts policymakers in a difficult situation, because these indirect effects act via a globalized food market and thus are beyond the control of policies of individual nations. Because bioenergy and, in particular, modern biofuels are regarded as a valuable option to reduce emissions from burning fossil fuels, it is thus important to understand if and potentially how locally implementable policies can contribute to reducing bioenergy-induced emissions.

## The findings

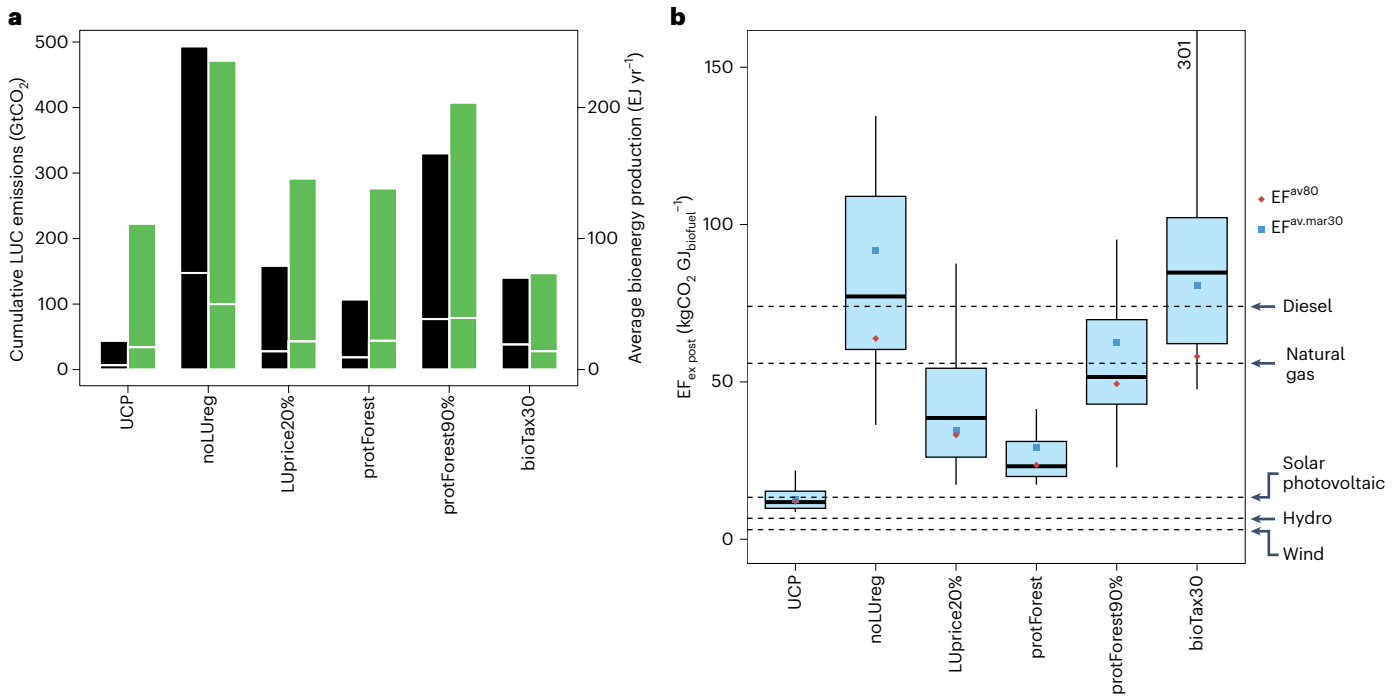
With an average emission factor (EF) of 92 $kgCO_2\,GJ^{-1}$, we find that the production of modern biofuels, if averaged over a 30-year period, causes land-use-change emissions that are higher than those from burning fossil diesel (Fig. 1). If policymakers tax bioenergy according to these average expected emissions, that is, apply a similar carbon price to a litre of biofuels as to a litre of diesel, the total future bioenergy-induced emissions decrease, as the demand is reduced. However, we show that such a policy cannot bring down the high average emissions that are attributed to biofuels. Only strict and globally comprehensive protection of natural land will reduce the EF and hence, only then, will those biofuels that replace fossil fuels effectively reduce $CO_2$ emissions.

## The study

This study used the integrated assessment modelling framework REMIND-MAgPIE coupling the energy and the land systems to derive alternative transformation scenarios consistent with limiting global warming well below 2 °C. The scenarios differ with respect to assumptions on land-use and energy policies, which have a large influence on $CO_2$ emissions from land-use change and also affect the amount of bioenergy used to fulfil the global energy demand. By deriving a counterfactual scenario, in which bioenergy is not available and hence land-use-change emissions are lower, we can attribute emissions to bioenergy production and derive an EF (emissions per unit of biofuel produced). In comparison to previous studies that analysed biofuel EFs, our approach using future climate change mitigation pathways allows us to compare the EF in the light of different policy frameworks, which we find are the most important to determine the emissions that can be expected from producing biofuels.

## Recommendations for policy

- Pushing for globally comprehensive land protection is the most effective way to reduce the high indirect land-use-change emissions associated with modern biofuel production from energy crops.
- A price on all $CO_2$ emissions from land clearing — not limited to direct bioenergy-related land conversion — is an effective and efficient instrument to protect land and reduce emissions from biofuels.
- Pricing all land carbon pools even at a substantial discount below the energy sector $CO_2$ price is more effective than a full protection scheme that covers only 90% of all forests globally.
- Given the deficiencies of current global land protection, indirect greenhouse gas emissions from biofuels need to be regulated as stringently as greenhouse gas emissions from fossil fuels.
- Combining biofuel production with carbon capture and storage can mitigate the high emissions, but even then, biofuels have a negative climate balance on a 30-year time horizon.




| Scenario | Land-use (LU) sector policies | Energy sector policies |
|---|---|---|
| UCP | Uniform carbon price (UCP) on all greenhouse gases at energy sector level | Bioenergy is treated as carbon neutral |
| noLUreg | No LU regulatory policies | Bioenergy is treated as carbon neutral |
| LUprice20% | UCP at 20% of the energy sector level on all greenhouse gases | Bioenergy is treated as carbon neutral |
| protForest | 100% of all forests are protected | Bioenergy is treated as carbon neutral |
| protForest90% | 90% of all forests are protected | Bioenergy is treated as carbon neutral |
| bioTax30 | No LU regulatory policies | Carbon price on bioenergy at the level of fossil diesel |

**Fig. 1 | Bioenergy-induced land-use-change (LUC) $CO_2$ emissions, bioenergy production and biofuel EFs under six different policy assumptions.** **a**, Cumulative (2020–2100) global bioenergy-induced LUC emissions (black) and bioenergy production given as the average annual global production (green). White horizontal bars indicate 2020–2050 values. **b**, Biofuel EFs in different metrics. The red markers show the average 80-year EF, the blue markers the weighted average 30-year EF. The boxplots show the variation over time of the 30-year EF between 2025 and 2070. The minima and maxima of the box confine the interquartile range, the whiskers represent the 1st and 4th quartile (for bioTax30, '301' is the upper bound of the whiskers), and the centre lines are the median value. Figure adapted with permission from L. Merfort et al. *Nat. Clim. Change* https://doi.org/10.1038/s41558-023-01697-2 (2023), Springer Nature Ltd.

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**Further reading**

1. Wise, M. et al. Implications of limiting $CO_2$ concentrations for land use and energy. *Science* **324**, 1183–1186 (2009).
**This study showed how bioenergy in an uncontrolled land-use system leads to massive land-use-change $CO_2$ emissions that are self-amplifying due to feedback with the energy sector, where the lower remaining carbon budget increases the demand for bioenergy.**
2. Yeh, S., Witcover, J., Lade, G. E. & Sperling, D. A review of low carbon fuel policies: principles, program status and future directions. *Energy Policy* **97**, 220–234 (2016).
**This study gives an overview of the status of low-carbon fuel standards (in particular biofuel policies) and shows that current**

**policies aimed at promoting biofuels to reduce carbon emissions rely on specific biofuel EFs ('carbon intensity standards').**

3. Daioglou, V. et al. Progress and barriers in understanding and preventing indirect land-use change. *Biofuel. Bioprod. Biorefin.* **14**, 924–934 (2020).
**This literature review on indirect land-use change from biofuels supports one of our main findings that indirect land-use change EFs are a poor guiding principle for evaluating the climate impact of biofuels due to high uncertainties.**
4. Heck, V., Gerten, D., Lucht, W. & Popp, A. Biomass-based negative emissions difficult to reconcile with planetary boundaries. *Nat. Clim. Change* **8**, 151–155 (2018).
**This study with a focus on bioenergy with carbon capture and storage shows the adverse side effects of bioenergy production in addition to the potentially high $CO_2$ emissions.**
5. Luderer, G. et al. Impact of declining renewable energy costs on electrification in low-emission scenarios. *Nat. Energy* **7**, 32–42 (2022).
**This study shows how declining renewable-energy costs can substantially reduce the reliance on carbonaceous fuels (such as biofuels) without missing climate targets.**

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**Competing interests**
The authors declare no competing interests.