Quantifying the land-based opportunity carbon costs of onshore wind farms

Abstract

The development of onshore wind energy impacts the land where it is constructed, together with competition for natural resources between the energy and land sector. The loss of terrestrial carbon stocks and ecosystem services from land use change to wind farms can be interpreted as the opportunity cost that landowners give up by choosing to construct wind farms on their land. Here, we spatially quantify the impact onshore wind farms have on land when we factor in the opportunity carbon (C) costs. We found that, the construction of 3848 wind turbines in Scotland generated 4.9 million tonnes of carbon dioxide (CO_2) emissions from land use change. On average the emission intensity of land use change in peatland is 560 g CO_2 kWh^{-1}, in forestry is 88 g CO_2 kWh^{-1}, in cropland is 45 g CO_2 kWh^{-1}, and in pastureland is 30 g CO_2 kWh^{-1}. In the worst land use change scenario, the displacement of Dystrophic basin peat habitats generated 1760 g CO_2 kWh^{-1}, which is comparable to the life cycle emissions of fossil-fuel technologies such as coal and gas-fired electricity generation. In arable land, the loss of harvestable crop to wind power was forfeited for a gain in opportunity costs up to £15.4 million over a 25 year operating life. Considering the short-term value of CO_2 in the trading market, the opportunity carbon costs of onshore wind farms can range from £0.3 to £65.0 per MWh of electricity generated per year. These findings highlight that the preservation of terrestrial carbon stocks and crop production in the land sector require the development of new payment schemes that can compete economically against the monetary benefits that landowners can access from lease agreements agreed with energy companies. This ensures also that wind turbines are geographically placed to protect ecosystem C stocks, and to minimize the carbon intensity of the electricity generated.

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