FYI: How NRDC Calculated Forest and Fossil Fuel Carbon Equivalencies

The global terrestrial carbon stock—meaning the carbon held in the trees, plants, wetlands, peatlands, and soils of Earth's landmasses—is often estimated at 2,500 gigatons.[1] As compared to all other terrestrial ecosystems, forests hold by far the most carbon, with the global total estimated to be as high as 2,150 gigatons.[2] Taking one step further, recent studies of the boreal forest carbon stock have found a median value, taken from a survey of existing research, of 1,095 gigatons.[3] Numbers for all global forests, and the global boreal forest specifically, include carbon stored in wetlands and peatlands, as these often occur throughout forest ecosystems.

In order to contextualize these numbers, we have broken them down into a number of equivalencies. The first breakdown we frequently use is in regard to the carbon that current research suggests is present in Canada's portion of the boreal forest. To reach this number, we multiplied the extent of the global boreal forest occurring in Canada—28 percent[4]—by the total carbon estimated in boreal forest ecosystems—1,095 gigatons. The result of this basic calculation is **306.6 gigatons of carbon**. Similar calculations can be applied to other boreal forest areas and could be refined based on country- or region-specific research. However, we believe that the Canadian boreal forest shares similar characteristics with the entirety of the global boreal forest, making this generalized approach acceptable in the absence of more granular data.

Next, we examined some of the latest research on economically recoverable (or "proven") fossil fuel reserves.[5] Because our source[6] presented these reserves in terms of exajoules (EJ), we also needed to convert the numbers given in the research into carbon. These numbers convert gigajoules (GJ) to carbon, with one GJ equivalent to 1 billion EJ.

We multiplied the EJ figures from Table 1 (see footnote 5) by 1 billion and then multiplied these again by the emissions factors contained in the Intergovernmental Panel on Climate Change's (IPCC) *Guidelines for National Greenhouse Gas Inventories* to convert the exajoules in fossil fuel

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[1] R. Lal, "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security," Science 304, no. 1623 (June 2004): p. 1623

[2] Malhi, Y. et al, "The Carbon Balance of Tropical, Temperate and Boreal Forests," Plant, Cell and Environment, 22 (1992): p. 716.

[3] Corey J.A. Bradshaw and Ian G. Warkentin, "Global Estimates of Boreal Forest Carbon Stocks and Flux," Global and Planetary Change, 128, no. 27 (May 2015): p. 26. Earlier research found that 49% of forest carbon stocks occur in the boreal forest, but this research excluded peatlands and wetlands, both of which occur throughout the boreal forest zone. Malhi, Y. et al, "The Carbon Balance of Tropical, Temperate and Boreal Forests," Plant, Cell and Environment, 22 (1992): p. 716.

[4] Natural Resources Canada, "8 Facts About Canada's Boreal Forest," http://www.nrcan.gc.ca/forests/boreal/17394 (accessed August 30, 2017).

[5] Andruleit, H. et al, "Energy Study 2014. Reserves, resources and availability of energy resources," The Federal Institute for Geosciences and Natural Resources (BGR), 18 (2014): p. 15, table 1, available at: https://www.bgr.bund.de/EN/Themen/Energie/Downloads/energiestudie_2014_en.pdf;jsessionid=AEAE7D10395AE02CC1C4BCC29F872EA6.1_cid331?__blob=publicationFile&v=3.

[6] Ibid.

reserves into carbon (C) and carbon dioxide (CO2) values.[7] This results in the following equations and results:

- **Coal**: Anthracite + Lignite (see full equations below) = **548.72 billion tons of C** or 2.014 trillion tons of CO_2:
    - **Hard Coal (Anthracite)**: (17,148 EJ x 1,000,000,000 (GJ conversion) x 26.8 (anthracite C emission factor)) / 1,000 (kg to metric tons) = **459.57 billion tons of C**. If burnt, this would release 1.687 trillion tons of CO_2 (459.57 billion x 3.67 (C to CO_2 conversion factor)).
    - **Lignite**: (3,230 EJ x 1,000,000,000 (GJ conversion) x 27.6 (lignite C emission factor)) / 1,000 (kg to metric tons) = **89.15 billion tons of C**. If burnt, this would release 327.17 billion tons of CO_2 (89.15 billion x 3.67 (C to CO_2 conversion factor)).

- **Oil**: (9,136 EJ (conventional crude, oil sand, extra heavy, and shale) x 1,000,000,000 (GJ conversion) x 20 (crude oil C emission factor)) / 1,000 (kg to metric tons) = **182.72 billion tons of C**. If burnt, this would release 671 billion tons of CO_2 (182.72 billion x 3.67 (C to CO_2 conversion factor).
    - **NOTE**: We used the 20 kg/GJ figure for all oil for the sake of simplicity. A more specific estimate is possible and would be higher due to the emissions factors of oil sand and tar sand compared to conventional crude.

- **Gas**: (7,526 EJ (conventional and non-conventional gas) x 1,000,000,000 (GJ conversion) x 15.3 (natural gas C emission factor)) / 1,000 (kg to metric tons) = **115.15 billion tons of C.** If burnt, this would release 422.59 billion tons of CO_2 (C to CO_2 conversion factor).

Taking these numbers together, we can see that total recoverable **fossil fuel reserves are estimated to contain 846.59 billion tons of carbon**. Because this number can be misleading—only a portion of these reserves are currently under development, we also include the estimated carbon in oil, coal, and gas reserves currently under production or development. This is estimated to be **257 billion tons of carbon**.[8]

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[7] Garg, A. et al, "2006 IPCC Guidelines for National Greenhouse Gas Inventories," Intergovernmental Panel on Climate Change (2006): p. 1.20, Table 1.3, available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf.

[8] Muttit, G., "The Sky's the Limit: Why the Paris Climate Goals Require a Managed Decline of Fossil Fuel Production," Oil Change International (September 2016): p. 18, Table 3, available at http://priceofoil.org/content/uploads/2016/09/OCI_the_skys_limit_2016_FINAL_2.pdf (figures converted to C from CO_2).