WHAT ARE THE NET GREENHOUSE GAS EMISSIONS FROM LOGGING IN CANADA?

Matthew Bramley and Graham Saul,
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Matthew Bramley (1967-2022)

This report is dedicated to the memory of its lead author, Matthew Bramley, who passed away just before its publication after a long fight with cancer.

Matthew made a significant contribution to understanding and advancing climate policy in Canada. He received a PhD in theoretical chemistry from the University of Cambridge before shifting gears, first volunteering and then working for Greenpeace as an anti-toxics campaigner in the 1990s.

From 2001–11, Matthew was Director, Climate Change at the Pembina Institute, where he became one of Canada's best known advocates for effective government action to reduce greenhouse gas emissions. He brought intellectual integrity to his climate work, refusing to compromise on the facts in the face of political resistance. The laws of atmospheric science dictated his policy recommendations, not the political sensitivities of the party in power on Parliament Hill.

Matthew left Canada for Europe in 2012 and eventually took up a job teaching math in Britain in 2016. He moved back to Canada in 2020 after being diagnosed with cancer and soon began offering his services to Nature Canada and the Natural Resources Defense Council as we sought to better understand the climate change impacts of logging in Canada.

Matthew devoted his deep scientific and mathematical expertise to the environmental movement because he believed in the power of political activism but felt that it needed to be backed up by the highest level of scientific rigor in order to succeed. Despite experiencing significant health challenges, Matthew undertook groundbreaking work over the past two years that revealed fundamental flaws with Canada's approach to forest carbon and logging emissions. This paradigm-shifting report was his most recent contribution.

Beneath his uncompromising intellect, Matthew was a compassionate and loving man. We mourn the loss of this giant mind and kind soul, and celebrate his significant legacy.

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Executive Summary

The Government of Canada does not provide an answer to the question "What are the annual net greenhouse gas emissions attributable to logging in Canada?" This is despite the fact that every April, Environment and Climate Change Canada (ECCC) publishes a national greenhouse gas (GHG) inventory report that presents clear annual net emissions figures for all other key industry sectors. Instead of stating the net GHG emissions from logging, the government uses confusing or misleading terms, both in the national inventory report (NIR) and in other key publications. It also disperses, in multiple locations in the NIR and the associated "common reporting format (CRF) tables"[2], the disaggregated figures that need to be pieced together to calculate Canada's net logging emissions. However, the NIR and the CRF tables (plus missing numbers that must be requested in certain cases from ECCC officials) do contain enough information to enable analysts wishing to estimate net logging emissions to do so – *using the government's own numbers*. Our calculations find that Canada's net logging GHG emissions in 2020 were 75 Mt CO_2e (megatonnes of carbon dioxide equivalents), which is more than 10% of Canada's total emissions as reported in the national inventory. Furthermore, net logging emissions were – again using the government's own numbers – higher than oil sands emissions during 2005–18 (inclusive), and higher than electricity emissions in 2005 and during 2011–20 (inclusive).

Our definition of net logging emissions in a given year is the sum of the following three items. We believe that this definition is reasonable because it focuses on the emissions and removals[3] that can reasonably be considered the responsibility of the logging industry, or reasonably attributed to it. For example, our definition excludes lands that have never yet been logged.

- We start with the amount of emissions that would occur if all the carbon extracted by logging went immediately into the atmosphere. We call this item "Carbon in harvested wood" (in CO_2 terms).

- We then recognize that some of the emissions in the first item are, in reality, deferred into the future because some wood carbon is kept out of the atmosphere in the form of long-lived products, notably construction materials. Net emissions therefore have to be lowered by the net amount of those deferred emissions. We call these "Net carbon added to long-lived products" (in CO_2 terms).

- We then further recognize that nearly all logging in Canada is followed by forest regeneration, and that this tree regrowth pulls CO_2 back out of the atmosphere. Net emissions must therefore be further lowered by the net amount of CO_2 equivalent (CO_2e) that the regrowth removes. We call this "Removals from re-growth after logging".

Net logging emissions are then the sum of the three items above. The first item is large and positive, while the second and third items are nearly always negative, so adding the three together is generally equivalent to taking a large positive number and subtracting two smaller positive numbers (see the figure at the end of Sec. 2). Following our definition, Table ES1 shows, highlighted in darker grey, the results of our calculation of Canada's net logging GHG emissions for each year of the period 2005–20 (the numbers may not add exactly due to rounding). Tables 1–3 give a good illustration of the lengths that one needs to go to to piece together the numbers in Table ES-1. Table ES-1 shows that net logging emissions in 2020 were 75 Mt CO_2e, which is more than 10% of Canada's total emissions as reported in the national GHG inventory.

Table ES1. The components of annual net logging GHG emissions, Mt CO_2e (nearest Mt):

Year: 20	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
Carbon in harvested wood	200	182	165	143	122	144	150	152	155	155	160	159	158	159	143	142
Net carbon added to long-lived products	−55	−50	−38	−16	2	−12	−15	−20	−19	−19	−25	−27	−26	−24	−17	−18
Removals from re-growth after logging	−25	−25	−27	−33	−45	−40	−43	−46	−47	−49	−45	−47	−49	−49	−54	−49
Net logging emissions	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75

Note: negative numbers in rows 2 and 3 represent respectively *positive* amounts of (i) carbon added to long-lived-products and (ii) CO_2 removed from the atmosphere.

Table ES2 compares our estimates of net logging emissions with the national GHG inventory's figures for two other key industry sectors, oil sands production and electricity generation. The years in which oil sands or electricity emissions were higher than net logging emissions are highlighted in the table in darkest grey, and the years in which they were lower than net logging emissions are highlighted in mid-grey. Net logging emissions were higher than oil sands emissions during 2005–18 (inclusive), and net logging emissions were higher than electricity emissions in 2005 and during 2011–20 (inclusive).

Table ES2. Annual GHG emissions from logging (net), oil sands and electricity, Mt CO_2e, nearest Mt:

Year: 20	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
Logging	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75
Oil sands	35	41	44	45	49	54	56	62	65	70	73	70	77	82	83	81
Electricity	118	112	120	109	94	95	87	83	80	76	80	74	73	63	62	56

There are two ways in which our estimates of net logging emissions are deliberately conservative. That is, there are positive sources of emissions quantified in Canada's GHG inventory that we could have opted to include in our estimates but that we have chosen to exclude. First, our estimates are restricted to what the GHG inventory calls "forest land remaining forest land". This means that we exclude the conversion of forest land to other uses – the official definition of deforestation. Second, our estimates do not include emissions from the logging industry's use of fossil fuels, notably in pulp and paper mills. In addition, Canada's GHG inventory has a number of limitations that cause our estimates to be likely further underestimated. For example, the inventory does not currently capture the emissions resulting from industrial logging's creation of substantial areas of roads and roadside surfaces that remain essentially barren while the forest regrows ("logging scars").

The government's "headline number" for net GHG emissions from forest land is something that it most commonly refers to as the "combined net flux". This is close to zero (a small negative number of Mt CO_2e in most years), likely giving many people the impression that net logging emissions are approximately zero – and that the logging industry is approximately carbon neutral. We are able to exactly reproduce the NIR's "combined net flux" numbers, and they turn out to be equal to the sum of net logging emissions (large and positive) and a "sink" of removals (large and negative) that cannot reasonably be associated with logging operations. This sink is generated by the regrowth of trees that have reached commercial maturity after major wildfires throughout the "managed forest", a very large area that includes a considerable proportion of primary forest that has not yet been industrially

logged. As we have shown previously in detail, the government's inclusion of this sink in its "combined net flux" is part of its highly biased procedure for excluding all major wildfires from the national GHG inventory, as well as a departure from the international rules for GHG inventories (as agreed through the Intergovernmental Panel on Climate Change). Regardless, this sink would not reasonably be included in any calculation of net logging emissions.

1. The Government of Canada does not provide an answer to the question: what are the net greenhouse gas emissions from logging in Canada?

The Government of Canada does not provide an answer to the question "What are the annual net greenhouse gas emissions attributable to logging in Canada?" This is despite the fact that every April, Environment and Climate Change Canada (ECCC) publishes a national greenhouse gas (GHG) inventory report that presents clear annual net emissions figures for all other key industry sectors, such as oil and gas production, electricity generation, chemicals manufacturing, iron and steel production, etc.

Instead of stating the net GHG emissions from logging, the government uses confusing or misleading terms, both in the national inventory report (NIR) and in other key publications (for details, see Sec. 6). It also disperses, in multiple locations in the NIR[4] and the associated "common reporting format (CRF) tables"[5,6] the disaggregated figures that need to be pieced together to calculate net logging emissions – as will be detailed in Sec. 2 below.

While the government does not state the net GHG emissions from logging, the NIR and the CRF tables do contain a relatively detailed accounting of the estimated carbon flows in and out of Canada's forests, within which many (although not all) basic components are disaggregated. Analysts wishing to estimate Canada's net logging emissions can therefore do so – *using the government's own numbers* – by making the appropriate selections and combinations of forest carbon components of the GHG inventory. This is not a simple task, as it requires a good understanding of the meanings of the multiple components and the knowledge of where to find them in a voluminous set of materials. In addition, missing numbers must in certain cases be requested from ECCC officials.

2. How we can use the government's numbers to obtain a reasonable and understandable answer

We believe that a definition of net logging emissions in a given year that is both reasonable and relatively easy to understand is a combination of the following three items:

- We start with the amount of emissions that would occur if all the carbon extracted by logging in the given year went immediately into the atmosphere. This amount, which we call item #1, clearly quantifies the scale of logging in carbon dioxide (CO_2) terms, and recognizes the fact that most of the carbon extracted by logging quickly ends up in the atmosphere as CO_2.

- We then recognize that some of the emissions in item #1 are, in reality, deferred into the future because some wood carbon is kept out of the atmosphere in the form of long-lived products, notably construction materials. The emissions in item #1 therefore have to be lowered by the net amount of those deferred emissions in the given year. We call the net amount of deferred emissions item #2. This amount clearly quantifies the contribution of long-lived products to reducing net logging emissions.

- We then further recognize that nearly all logging in Canada is followed by forest regeneration, that this tree regrowth pulls CO_2 back out of the atmosphere through negative emissions, referred to as removals,[7] and that this regrowth after logging is an integral part of logging practices. Item #1 must therefore be further lowered by the net amount of CO_2 equivalent (CO_2e) that the regrowth removes from the atmosphere in the given year. We call this amount item #3. (Sec. 2.3 explains why this is a CO_2e, rather than a pure CO_2 figure.)

We believe that this is a reasonable definition of net logging emissions because it includes the emissions that can reasonably be considered the responsibility of the logging industry, as well as the removals that can reasonably be attributed to the industry, while excluding emissions and removals that do not meet that test. For example, our definition excludes lands that have never yet been logged. These lands may be part of companies' plans or rights for future logging, but as long as the companies do not meaningfully manage lands in the present, they cannot reasonably attribute to themselves nor be held responsible for what occurs there.

The following subsections describe how we assemble items #1–3 above and then combine them. Before doing so it is important to note that we restrict each item to what the GHG inventory calls "forest land remaining forest land" – land on which trees are replanted or allowed to naturally regenerate after logging. This means that we exclude emissions and removals associated with (i) the conversion of land that had until then been forest to other uses (the official definition of deforestation) such as agriculture, oil and gas operations, and urban areas; and (ii) the creation of new forest land (afforestation) in areas that had previously been unforested[8]. We must mention this restriction here, as it determines the details of the descriptions below. It also contributes to the conservativeness of our net logging emissions estimates (further elaborated in Sec. 5).

2.1 Item #1: Carbon in harvested wood (in CO_2 terms)

This is the CO_2 equivalent of the total amount of carbon extracted from "forest land remaining forest land" (FLFL) by logging operations in a given year. It is an accepted fact that nearly all of the carbon in harvested wood ends up at some point being oxidized into CO_2 and released to the atmosphere. If all of this carbon were oxidized and released to the atmosphere in the same year, item #1 is the amount of logging-related emissions that would occur.

Table 1 summarizes the multiple steps that we need to go through to assemble this item from numbers in the GHG inventory (plus some missing numbers provided by ECCC officials). First we take the amount of carbon in *all* harvested wood. This is provided in NIR Table 6-7 but is rounded there so we take instead the unrounded figure from the CRF tables. Then, because we are restricting ourselves to FLFL, we need to subtract the carbon in wood that came from deforestation, and in firewood taken from non-forest land. These two components are also provided in NIR Table 6-7 but some of the years are missing so the full data must be requested from ECCC. Finally we need to convert the carbon figure obtained into CO_2 terms.

Table 1. How we assemble item #1:

operation	Component	Source
(none)	Carbon in all harvested wood	CRF Table 4.Gs1, sum of cells B34 and B45 for each year
minus	Carbon in harvested wood from forest conversion (deforestation)	NIR part 1, Table 6–7, sum of rows 3–5 (data for missing years was provided by ECCC officials)
minus	Carbon in residential firewood taken from agricultural and urban (non-forest) land	NIR part 1, Table 6–7, sum of rows 7–8 (data for missing years was provided by ECCC officials)
multiply by 44/12	Sum of three components above, multiplied to convert mass of carbon to mass of CO_2	44 is the molecular weight of CO_2; 12 is the atomic weight of carbon

2.2 Item #2: Net carbon added to long-lived products (in CO_2 terms)

This is the CO_2 equivalent of the addition, in a given year, to the "pool" of carbon in wood harvested from "forest land remaining forest land" (FLFL) that is being kept out of the atmosphere in the form of long-lived products. This pool of carbon residing in long-lived wood products, notably construction materials, grows when carbon is added to it in the form of newly produced products, and shrinks when carbon is lost from the pool to the atmosphere as products reach the end of their life. Item #2 is a net amount combining the growth of the pool due to the addition of new products and the shrinkage of the pool due to the loss of end-of-life products.

Table 2 summarizes the steps we need to go through to assemble this item from numbers in the GHG inventory (plus, again, some missing numbers provided by ECCC officials): it is a good illustration of the lengths that one needs to go to to piece together what should, arguably, be an easily available number. First we take the total emissions from wood products – which span the range from firewood, where the emissions are likely to come from wood harvested in the same year, to lumber where some of the emissions will be from wood cut decades earlier. This number is provided in NIR Table 6-7 but is rounded there so we take instead the unrounded figure from the CRF tables. Then, because we are restricting ourselves to FLFL, we need to subtract the emissions from products that originated from deforestation, and from firewood taken from non-forest land. These two components can be found in NIR Tables 6-8 and 6-7 respectively but some of the years are missing so the full data must be requested from ECCC; also, the carbon numbers in Table 6-7 must be converted into CO_2 terms. Finally we need to subtract the carbon in harvested wood from FLFL (in CO_2 terms) – which is item #1 as already described in Sec. 2.1.

Overall, what we are doing here is assembling the actual estimated emissions in the given year from wood products originating from FLFL, then subtracting the hypothetical emissions that would have occurred if *all* of the carbon extracted from FLFL by logging in that year were oxidized and released to the atmosphere in the same year. The resulting number is usually negative; if so, it represents the net positive amount of carbon that has been added to the long-lived-product carbon pool of emissions that are deferred into the future. For example, if item #2 is calculated to be −30 megatonnes (Mt) of CO_2 for the given year, then an additional net +30 Mt of carbon (in CO_2 terms) must have built up in long-lived wood products in that year.

Table 2. How we assemble item #2:

operation	Component	Source
(none)	Total emissions from harvested wood products	CRF Table 4, cell B26
minus	Emissions from harvested wood products originating from forest conversion (deforestation)	NIR part 1, Table 6–8, row 2 for each year (data for missing years was provided by ECCC officials)
minus	Carbon in residential firewood taken from agricultural and urban (non-forest) land, mutiplied by 44/12 to convert to CO_2	NIR part 1, Table 6–7, sum of rows 7–8 (data for missing years was provided by ECCC officials)
minus	Carbon in harvested wood from FLFL (in CO_2 terms)	This is item #1, calculated in Sec. 2.1

2.3 Item #3: Removals from regrowth after logging (CO_2e)

This is the net amount of CO_2 equivalent (CO_2e) removed from the atmosphere by tree regrowth on "forest land remaining forest land" (FLFL) after logging. This item is "net" because it incorporates not just removals from tree growth but also emissions from the decay of dead wood, litter and soil organic matter (calculated by Natural Resources Canada's forest carbon model),[9] as well as small amounts of emissions from activities directly related to logging, namely controlled burning and soil drainage. (The controlled burning emits small amounts of methane and nitrous oxide, which means that the total is a CO_2e rather than a pure CO_2 figure.)

An approximation of this item is available only graphically in NIR Figure 6–3 (see Table 3), for which the NIR does not provide the source data. This data therefore has to be requested from ECCC.[10] The numbers are invariably negative, representing a positive amount of CO_2 removed from the atmosphere.

Table 3. How we obtain item #3:

operation	Item	Source
(none)	Net removals from tree regrowth after logging on FLFL	NIR Figure 6–3, "Anthropogenic Component, past forest management activities" (precise source data for the figure was provided by ECCC officials)

2.4 Combining items #1–3 to calculate net logging emissions

Following our definition of net logging emissions (see the start of Sec. 2 above), we can now finally calculate those emissions by:

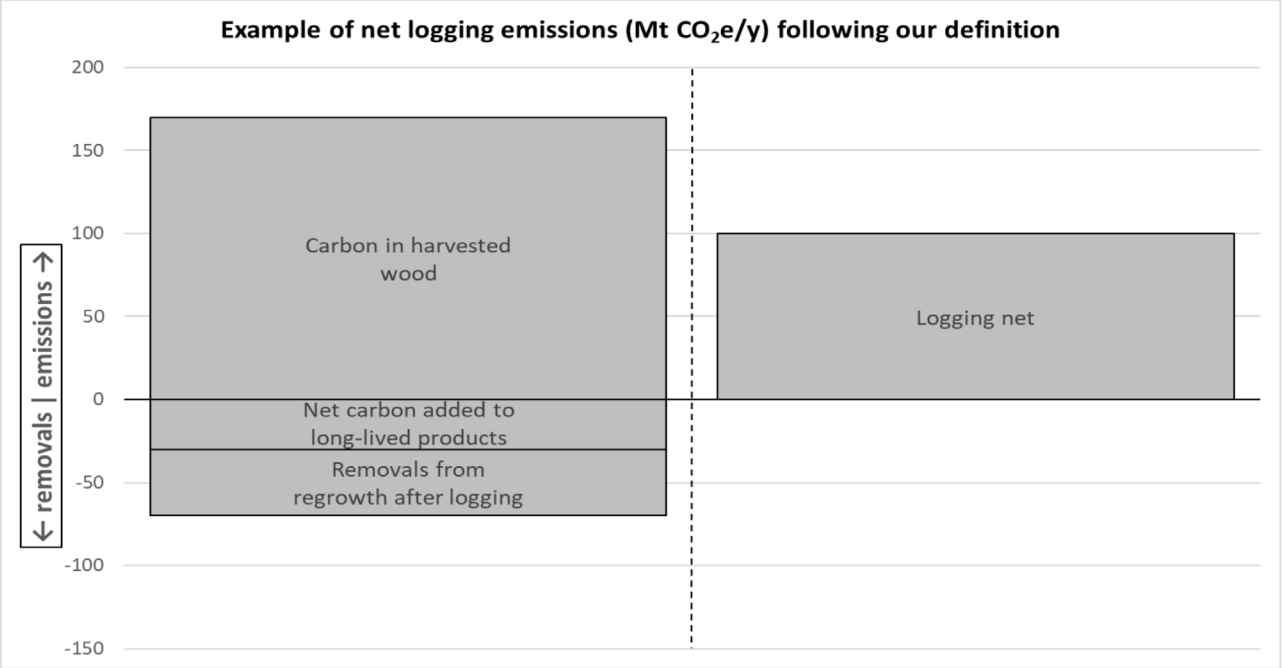
- taking item #1, the carbon in harvested wood (in CO_2 terms), which is a large positive number, and then
- lowering it by adding two smaller numbers that are nearly always negative:

    - item #2, the net carbon added to long-lived products (in CO_2 terms) (when negative this item represents a positive amount of carbon *added* to long-lived-products), and
    - item #3, the removals from regrowth after logging (CO_2e) (invariably negative, this item represents a positive amount of CO_2 *removed* from the atmosphere)

The sign conventions (the meaning of positive and negative numbers) that we are using for items #2 and 3 can be confusing but have been chosen to align with the international rules for national GHG inventories. An example may make things clearer: Suppose that, in a given year:

- Canada extracts from its forests an amount of wood containing 170 Mt CO_2 -worth of carbon (item #1)
- A net amount of 30 Mt CO_2 -worth of carbon gets added to the pool of long-lived wood products (i.e. the pool gets bigger); this means that item #2 is −30 Mt
- Regrowth after logging removes a net amount of 40 Mt CO_2 from the atmosphere, with the carbon in that CO_2 stored in growing trees; this means that item #3 is −40 Mt.

Net logging emissions for that year are therefore 170 + (−30) + (−40) = 100 Mt CO_2.This is illustrated in the following figure.



3. Our answer to the question: what are the net greenhouse gas emissions from logging in Canada?

Table 4 shows, highlighted in darker grey, the results of our calculation of Canada's net logging GHG emissions for each year of the period 2005–20, following our definition as set out in Sec. 2. As previously emphasized, all the ingredients of our calculations are taken from the government's latest GHG inventory (plus missing numbers provided in certain cases by ECCC officials). 2020 is the most recent year for which the inventory provides figures. The first three rows of the table show the respective contributions of our three items (see Sec. 2) making up net logging emissions (the numbers may not add exactly due to rounding).

Net logging emissions in 2020 were 75 Mt CO_2e, which is more than 10% of Canada's total GHG emissions as reported in the national inventory.[11] Net logging emissions have fallen in recent years in line with a decline in the amount of carbon in harvested wood, which in turn correlates with a fall in the annual area of forest logged in Canada from 1,114 kilohectares (kha) in 2005 to 757 kha in 2019 (latest year available).[12] At the same time, the net amount of carbon being added each year to long-lived products has generally been declining, while removals from tree regrowth after logging have risen. It is notable that carbon removals from tree regrowth after logging continue to fall far short of the amount of carbon being extracted from forests by logging.

Table 4. The components of annual net logging GHG emissions, Mt CO_2e (nearest Mt):

Year: 20	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
Carbon in harvested wood	200	182	165	143	122	144	150	152	155	155	160	159	158	159	143	142
Net carbon added to long-lived products	−55	−50	−38	−16	2	−12	−15	−20	−19	−19	−25	−27	−26	−24	−17	−18
Removals from re-growth after logging	−25	−25	−27	−33	−45	−40	−43	−46	−47	−49	−45	−47	−49	−49	−54	−49
Net logging emissions	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75

Note: negative numbers in rows 2 and 3 represent respectively *positive* amounts of (i) carbon added to long-lived products and (ii) CO_2 removed from the atmosphere.

4. Net logging emissions compared to those of other key industry sectors

Table 5 compares our estimates of net logging emissions with the national GHG inventory's figures[13] for two other key industry sectors, oil sands operations and electricity generation. As noted in Sec. 1, ECCC's NIR presents each year clear emissions figures for key industry sectors such as oil sands and electricity.

The oil sands sector rightly receives much attention in discussions of Canada's approach to reducing GHG emissions, as it accounts for over 10% of the country's total emissions and has seen its emissions more than double over the past 15 years. Electricity generation has also accounted for over 10% of total national emissions for most of the past 15 years, and is of particular interest as the sector where governments have probably made the greatest efforts to date to reduce emissions, notably by phasing down the use of coal.[14] As a result, emissions from electricity generation are now less than half of what they were 15 years ago.

Table 5. Annual GHG emissions from logging (net), oil sands and electricity, Mt CO_2e, nearest Mt:

Year: 20	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
Logging	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75
Oil sands	35	41	44	45	49	54	56	62	65	70	73	70	77	82	83	81
Electricity	118	112	120	109	94	95	87	83	80	76	80	74	73	63	62	56

The years in which oil sands or electricity emissions were higher than net logging emissions are highlighted in the table in darkest grey, and the years in which they were lower than net logging emissions are highlighted in mid-grey. Net logging emissions were higher than oil sands emissions during 2005–18 (inclusive), and net logging emissions were higher than electricity emissions in 2005 and during 2011–20 (inclusive).

The government's figures for oil sands and electricity reproduced in Table 5 cover (according to the NIR):

- oil sands: "Stationary combustion, onsite transportation, electricity and steam production, fugitive and process emissions from: ... crude bitumen mining and extraction; ... in-situ extraction of crude bitumen including primary extraction, cyclic steam stimulation (CSS), steam-assisted gravity drainage (SAGD) and other experimental techniques; [and...] crude bitumen and heavy oil upgrading to synthetic crude oil"

- electricity: "Combustion and process emissions from utility electricity generation, steam production (for sale) and transmission" but exclude "utility owned cogeneration at industrial sites".[15]

5. Our figures for net logging emissions are likely underestimated

There are two ways in which our estimates of net logging emissions are deliberately conservative. That is, there are positive sources of emissions quantified in Canada's GHG inventory that we could have opted to include in our estimates but that we have chosen to exclude:

- Our estimates are restricted (as already noted at the start of Sec. 2), to what the GHG inventory calls "forest land remaining forest land" – land on which trees are replanted or allowed to naturally regenerate after logging. This means that we exclude emissions and removals associated with the conversion of forest land to other uses – the official definition of deforestation – or with the creation of new forest land, i.e., afforestation. This makes our estimates conservative because Canada's latest GHG inventory estimates 16 Mt CO_2e of deforestation emissions in 2020, and similar numbers for earlier years,[16] but much smaller amounts of net removals from afforestation (0.24 Mt CO_2e in 2020, down from 0.95 Mt in 2005).[17] The deforestation, which results from processes such as the expansion of agriculture, oil and gas operations, and urban areas, is arguably more reasonably attributed to the sectors driving it than to the logging industry.
- Our estimates do not include emissions from the logging industry's use of fossil fuels, notably in its vehicles and pulp and paper mills. Arguably, pulp and paper production is an integral part of the logging industry, but at present it is often viewed as a separate economic sector. The GHG inventory estimates 7 Mt CO_2e of emissions from the use of fossil fuels in pulp and paper production in 2020, down from 9 Mt in 2005.[18]

In addition, bearing in mind that our estimates of net logging emissions are based entirely on components of Canada's GHG inventory, the inventory has a number of limitations that cause our estimates to be likely further underestimated:

- Our definition of net logging emissions excludes emissions from major (stand-replacing) wildfires and major insect infestations – as well as subsequent removals – on land where forests are regenerating after logging. We would have liked to include these fire- and insect-related emissions/removals in our definition, as we see a strong case for their inclusion on the basis that the logging industry can reasonably be held permanently responsible for all carbon flows on such land – consistent with the fact that our definition permanently attributes the removals occurring there to the industry. However, the GHG inventory does not include those fire- and insect-related emissions/removals in net removals from regrowth after logging (item #3 in our definition); it quantifies them only for the "managed forest" as a whole, a considerable proportion of which has not (yet) been industrially logged,[19] and not specifically for land that has already been logged.[20] We are therefore unable for now to include them. This likely leads to a systematic underestimation of logging emissions because the mean net annual value of the excluded fire- and insect-related emissions/removals (for the whole "managed forest") was 109 Mt CO_2e during 2005–20 and positive every year during that period.[21] However, we expect that only a small fraction of this figure represents net emissions on already-logged land, reasonably attributable to the logging industry.
- The GHG inventory does not currently capture[22] the emissions resulting from industrial logging's creation of substantial areas of roads and land areas ("logging scars") that remain essentially barren while the forest regrows.[23] We have previously estimated these emissions to be roughly on the order of 10 Mt CO_2 per year.[24]
- Logging figures used for the GHG inventory are obtained by Natural Resources Canada (NRCan) from provincial and territorial governments.[25] A recent investigation by Radio-Canada based on testimony from whistle-blowers concluded that logging levels reported by the Québec government are being systematically under-measured.[26] This raises the possibility that this problem is occurring more broadly, which would result in a significant underestimation of logging emissions.
- An omission from NRCan's forest carbon model, as used in the GHG inventory (it is also an omission from most physical measurements of GHG flows in Canada's forests), is full consideration of GHGs other than CO_2, notably methane. International rules for the forest portion of national GHG inventories do not consider methane except for the very small amounts emitted by fires.[27] However, recent

measurements in Ontario have shown that the climate forcing effect of methane fluxes in managed forests can be greater than that of CO_2.[28]

- Also as a result of the international rules for GHG inventories, Canada's inventory excludes (i) methane generated by the decay of Canadian wood in landfills (captured in the waste sector of the GHG inventory of the country where the wood is landfilled) and (ii) methane and nitrous oxide released when Canadian wood is burned as fuel (captured in the energy sector of the GHG inventory of the country where the wood is burned).[29]

5.1 Other considerations

Two further considerations relevant to assessing the GHG emissions attributable to logging in Canada are as follows:

- ECCC acknowledges that the forest carbon numbers in Canada's GHG inventory are subject to high uncertainty. Major sources of uncertainty include the details of carbon flows between trees and the atmosphere, and the timing of the release of carbon into the atmosphere from long-lived products as they reach the end of their life.[30] There are many other sources of uncertainty, most of which apply to our estimates of net logging emissions, since they are based entirely on the inventory.

- Canada's GHG inventory – and therefore our estimates of net logging emissions – includes "downstream" emissions that occur when carbon in wood harvested in Canada is oxidized into CO_2 and released to the atmosphere, regardless of whether those emissions occur in Canada or in countries that have imported Canadian wood products. In contrast, the inventory's emissions attributed to oil sands, for example, include only those related to the production of synthetic crude oil and do not include the higher emissions that occur "downstream" when the carbon in that oil is burned (oxidized) – a consequence of the international rules for GHG inventories. From the perspective of implementing effective policies to reduce industrial GHG emissions, what matters most is to compare figures from the national GHG inventory, as they will be the basis for assessing Canada's attainment of its GHG targets. The logging – oil sands comparison that we make in Sec. 4 reflects exactly that.

6. How and why do net logging emissions differ from the government's "combined net flux"?

As noted in Sec. 1, the Government of Canada does not provide an answer to the question "What are the annual net greenhouse gas emissions attributable to logging in Canada?" Instead, the government uses confusing or misleading terms, while dispersing (and in some cases providing only on request) the disaggregated figures that need to be pieced together to calculate net logging emissions (see Sec. 2). The latter are therefore effectively hidden.

In its NIR, the government provides a number for what it refers to as "the combined net flux from Forest Land and Harvested Wood Products – from forest harvest".[31] It then refers to the same quantity in other places using different words:

- elsewhere in the NIR, the "combined net flux" is referred to as the "total net flux from managed forests and resulting HWP [harvested wood products]"[32] and also as the "emissions and removals from the forest sector"[33]

- in *The State of Canada's Forests*, NRCan refers to the "combined net flux" as the "net emissions" "accounted for" by "human activities in Canada's managed forests"[34]

- ECCC's recent 2030 Emissions Reduction Plan refers to the "combined net flux" with the words "forestry… emitted".[35]

As detailed below, the "combined net flux" is close to zero (a small negative number of Mt CO_2e in most years). This likely gives many people the impression that net logging emissions are approximately zero – and that the logging industry is approximately carbon neutral – because they could be forgiven for thinking that "the forest sector", "human activities in managed forests" or "forestry" are synonymous with logging.

The fact that the government actually fails to state net emissions from logging, while simultaneously using language that can make its "combined net flux" sound very much like the net emissions from logging, is no doubt a central reason why the true scale of net GHG emissions from logging in Canada is not currently well understood. This is clearly evident in public discourse – notably in the media.

This raises the question of how and why our net logging emissions differ from the government's "combined net flux". The answer is that the "combined net flux" turns out to be equal to the sum of net logging emissions (large and positive) and a "sink" of removals (large and negative) that cannot reasonably be associated with logging operations. This sink – which we will refer to below as "item C" – is generated by the regrowth of trees that have reached commercial maturity after major wildfires throughout the "managed forest", a very large area that includes a considerable proportion of primary forest that has not yet been industrially logged.[36] In other words, in Canada's GHG inventory, are hiding in plain sight, subsumed within the broader quantity of "combined net flux".

The government describes its "combined net flux" as the sum of two items:

A. a large net sink of removals resulting mostly from tree growth throughout the "managed forest", which we take to be specifically "forest land remaining forest land" (FLFL) (although see note 2 under Table 6)

B. the total emissions from harvested wood products (HWPs, spanning the range from firewood, where the emissions are likely to come from wood harvested in the same year, to lumber where some of the emissions will be from wood cut decades earlier), originating from the same land as in item A.

We have quantified items A and B in the first two rows of Table 6 below, and their sum, the "combined net flux", in the third row. Item A (the FLFL net sink) is "Forest Land Remaining Forest Land" in NIR Table 6–1, of which we have used an unrounded version: the "Total Anthropogenic Component" in NIR Figure 6–3 (precise source data for the figure was provided by ECCC officials). The GHG inventory never actually states item B (emissions from HWPs originating from FLFL) but it is the combination of the first three components of our item #2 in Table 2 (Sec. 2.2). The item B numbers in Table 6 below are close to the "Harvested Wood Products" figures in NIR Table 6–1, but the former are slightly smaller because they have had subtracted from them the emissions from (i) products originating from forest conversion and (ii) residential firewood from non-forest land.

Now we come in more detail to the source of the difference between net logging emissions following our definition and the government's "combined net flux". The government's item A (the FLFL net sink) excludes areas significantly affected by "natural disturbances" on the basis that they are out of the control of human activity, i.e., the emissions are deemed not to be anthropogenic. This means that item A and

the “combined net flux” exclude, most notably, all emissions from the largest (stand-replacing) wildfires. The excluded areas are, however, re-inserted into item A (and into the “combined net flux”) once the trees have regrown to “commercial maturity” (after 76 years on average).[37] These commercially mature post-fire trees act as a large sink – labelled as item C in Table 6 – that the GHG inventory now considers to be anthropogenic. It is notable that a comparison of rows 1 and 4 of Table 6 shows that item C forms the majority of the entire FLFL net sink (item A). An approximation of item C is available only graphically as the “Anthropogenic Component, mature stands of natural disturbance origin” in NIR Figure 6–3 but precise data for the figure was provided by ECCC officials.

It is item C that is the sole difference between the government’s “combined net flux” and our net logging emissions: the last four rows of Table 6 show that if one subtracts item C from the “combined net flux”, one obtains exactly our logging emissions figures. The fact that item C is the sole difference is obscured by the difference of presentation in how the government breaks its number into constituent parts (items A and B as described in this section) and how we do so (items #1, #2 and #3 as described in Sec. 2).

Table 6. Reconciliation of our net logging emissions and the government’s “combined net flux”, Mt CO_2e (nearest Mt):

Year: 20	*05*	*06*	*07*	*08*	*09*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
A. FLFL net sink	−134	−133	−132	−136	−145	−136	−139	−141	−141	−141	−134	−136	−136	−134	−138	−130
B. Emissions from HWPs originating from FLFL	144	132	127	126	123	132	135	133	136	136	135	132	133	135	126	124
“Combined net flux” = A plus B	10	−1	−5	−10	−21	−4	−4	−9	−5	−5	1	−3	−3	1	−11	−6
C. Commercially-mature post-fire sink (part of A)	−109	−108	−105	−103	−100	−96	−96	−95	−94	−92	−89	−89	−87	−85	−84	−81
“Combined net flux” minus C	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75
Our net logging emissions	120	107	99	94	79	92	91	86	89	87	90	85	84	87	72	75

Note 1: numbers may not add/subtract exactly due to rounding.

Note 2: the “combined net flux” numbers in row 3 differ very slightly (by less than 1 Mt) from the numbers provided in the latest NIR.[38] This is because the latter incorporate a very small extra amount of net removals due to afforestation (“land converted to forest land”), given in CRF Table 4, cell B10. We can reproduce the NIR’s “combined net flux” numbers exactly by adding those extra removals to item A.

As we have shown previously in detail,[39] the government’s inclusion of this sink in its “combined net flux” is part of its highly biased procedure for excluding all major wildfires from the national GHG inventory, as well as a departure from the international rules for GHG inventories (as agreed through the Intergovernmental Panel on Climate Change). Regardless, this sink would not reasonably be included in any calculation of net logging emissions.

Canada’s GHG inventory currently says that all major wildfires and their associated emissions, as well as all subsequent removals as trees grow up to the point of commercial maturity, are natural, not anthropogenic, so must be excluded from the inventory’s net forest carbon figures (and not reported to the UN climate change secretariat). At the same time, the inventory says that the moment these trees become commercially mature, the large sink that they generate suddenly becomes anthropogenic and must be included in the inventory’s totals (and reported to the UN) – *even though the tree growth creating*

this sink involves no more human intervention than the wildfires whose emissions were excluded. The result is that the "combined net flux" represents a massive overreporting of net removals – equivalent to a massive underreporting of net emissions – from forest land. The size of the bias and overreporting of net removals is given precisely by item C, the commercially mature post-fire sink.

A further key consideration above and beyond this major bias is that a large fraction of item C likely occurs on lands that have not yet been logged. These lands may be part of companies' plans or rights for future logging, but as long as the companies do not meaningfully manage lands in the present, they cannot reasonably attribute to themselves, as part of net logging emissions, removals occurring there.

Conclusion

Key points from this report are as follows:

- The Government of Canada does not provide an answer to the question "What are the annual net greenhouse gas emissions attributable to logging in Canada?" – despite publishing clear annual net emissions figures for all other key industry sectors. Instead of stating the net GHG emissions from logging, the government uses confusing or misleading terms which likely give many people the impression that net logging emissions are approximately zero – and that the logging industry is approximately carbon neutral.
- We have adopted a definition of net logging emissions in a given year that focuses on reasonableness and being relatively easy to understand. Following that definition, we have been able to piece together disaggregated figures, dispersed in multiple locations in the national GHG inventory (plus missing numbers that had to be requested in certain cases from ECCC officials), in order to calculate Canada's net logging emissions – using the government's own numbers.
- Our calculations find that Canada's net logging GHG emissions in 2020 were 75 Mt CO_2e, which is more than 10% of Canada's total emissions as reported in the national inventory. Furthermore, net logging emissions were – again using the government's own numbers – higher than oil sands emissions during 2005–18 (inclusive), and higher than electricity emissions in 2005 and during 2011–20 (inclusive).
- There are two ways in which our estimates of net logging emissions are deliberately conservative. First, our estimates are restricted to what the GHG inventory calls "forest land remaining forest land". This means that we exclude the conversion of forest land to other uses – the official definition of deforestation. Second, our estimates do not include emissions from the logging industry's use of fossil fuels, notably in pulp and paper mills. In addition, Canada's GHG inventory has a number of limitations that cause our estimates to be likely further underestimated.

Endnotes

1. The authors would like to thank Jennifer Skene and Anthony Swift, both from NRDC, and Michael Polanyi and Priscilla Santos of Nature Canada, for their valuable input.
2. The NIR and the CRF tables together comprise Canada's complete GHG inventory. Although ECCC has overall responsibility for the inventory, all of its forest carbon figures are calculated by Natural Resources Canada (NRCan
3. In this paper, we use the words "removals" and "remove" exclusively to refer to the negative emissions that occur when growing trees absorb CO2 from the atmosphere. Removals in this sense are commonly called "carbon removals"
4. Environment and Climate Change Canada (2022a), National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada (https://unfccc.int/documents/461919)
5. Environment and Climate Change Canada (2022b), Common reporting format tables (https://unfccc.int/documents/461923).
6. The NIR and the CRF tables – both of which Canada is required to submit to the UN's climate change secretariat each year – together comprise Canada's complete GHG inventory. Although ECCC has overall responsibility for the inventory, all of its forest carbon figures are calculated by Natural Resources Canada (NRCan) using its models for forest carbon and harvested wood products (see Environment and Climate Change Canada (2022a), part 1, p.21,178).
7. In this paper, we use the words "removals" and "remove" exclusively to refer to the negative emissions that occur when growing trees absorb CO_2 from the atmosphere. Removals in this sense are commonly called "carbon removals".
8. Intergovernmental Panel on Climate Change guidelines for national GHG inventories define afforestation as "The direct human-induced conversion of land that has not been forested for a period of at least 50 years…", but note that this definition is specific to the Kyoto Protocol. See Intergovernmental Panel on Climate Change (2006), IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4 Chapter 4, p.4.72.
9. G. Stinson et al., "An inventory-based analysis of Canada's managed forest carbon dynamics, 1990 to 2008", Global Change Biology 17: 2227–2244 (2011), Figure 4.
10. We have verified that the numbers depicted in NIR Figure 6–3 include emissions from controlled burning and soil drainage, by exactly reproducing those numbers using figures from CRF Table 4, row 9 and Table 4(II), row 9, which explicitly include those emissions.
11. The inventory reported total emissions in 2020 of 672 Mt CO_2e, excluding land-use, land-use change and forestry (Environment and Climate Change Canada (2022a), part 1, Table ES–2). 75 Mt is 11% of 672 Mt, and 10% of (672 plus 75 Mt).
12. Natural Resources Canada, https://cfs.nrcan.gc.ca/statsprofile/forest/CA (accessed May 24, 2022).
13. Environment and Climate Change Canada (2022a), part 3, Table A10–2.
14. Ibid., part 1, p.41.
15. Ibid., part 3, Table A10–1.
16. Ibid., part 1, Table 6–1.
17. Ibid.
18. Ibid., part 3, Table A10–2.
19. See Matthew J. Bramley (2021), Canada's Approach to Forest Carbon, Quantification and Accounting: Key Concerns, Nature Canada, NRDC, Nature Québec and Environmental Defence, Sec. 4.1 (https://naturecanada.ca/wp-content/uploads/2021/10/Canadas-Approach-to-Forest-Carbon-Quantification-and-Accounting-Key-Concerns.pdf).

20. Emissions from major (stand-replacing) wildfires and major insect infestations, and subsequent removals, are provided in NIR Table 6–5, but the GHG inventory does not disaggregate these emissions and removals according to whether the land where they occur has been logged or not.
21. Ibid., sum of rows 11, 16 and 17 (data for missing years was provided by ECCC officials).
22. Wildlands League, Boreal Logging Scars (2019), p.52–56. Confirmed by NRCan officials, personal communication, May 2021.
23. Wildlands League, p.3.
24. Bramley (2021), Sec. 3.1.
25. Environment and Climate Change Canada (2022a), Part 2, p.150–151.
26. Radio-Canada, “Le ministère des Forêts du Québec est-il à la solde de l’industrie?”, March 4, 2021, https://ici.radio-canada.ca/nouvelle/1774723/foresterie-mesurage-terres-publiques-complaisance-gouvernement, accessed March 5, 2021.
27. Intergovernmental Panel on Climate Change (2019), 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 4 Chapter 4.
28. S.C. Thomas et al., “Managed forests and methane: recent research and prospects for best management practices”, in Y. Wang et al. (eds), “Forest management for climate change mitigation: recent innovations and research needs”, Handbook of Environmental Chemistry vol. 698, Springer (2022, in press).
29. Environment and Climate Change Canada (2022a), part 2, p.161.
30. For more detailed information see Bramley (2021), Sec. 2.2.
31. Environment and Climate Change Canada (2022a), part 1, p.11 (Executive Summary) and p.170 (chapter 6).
32. Ibid., part 1, p.57 (chapter 2).
33. Ibid., part 1, p.169 (chapter 6).
34. Natural Resources Canada (2022), The State of Canada’s Forests: Annual Report 2021, p.39.
35. Environment and Climate Change Canada (2022c), 2030 Emissions Reduction Plan: Canada’s Next Steps for Clean Air and a Strong Economy, p.70.
36. See Bramley (2021), Sec. 4.1.
37. Detailed references for this “wildfire exclusion procedure” are given in Bramley (2021), Sec. 4.1. They refer to the GHG inventory published in 2021, but the 2022 GHG inventory uses exactly the same procedure.
38. Environment and Climate Change Canada (2022a), part 1, p.11. The NIR text provides “combined net flux” numbers for 1990, 2005, 2009 and 2020 only.
39. Bramley (2021), Sec. 4.1.