Quebec's Climate Fair Share

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Introduction

Climate change is an inherently global problem – impacts of a changing climate are felt increasingly around the globe and the greenhouse gas (GHG) emissions that drive climate change and global heating are coming from all countries of the world and are circulating freely around the globe. No country can solve its own climate change crisis – actions in other countries have at least as important an effect on a country's climate risks than the actions taken by the country itself. This all points to the fact that addressing the climate crisis requires a large and unprecedented degree of international cooperation and such international cooperation is hard to imagine without countries seeing all other countries doing their fair share of the global effort. In the words of the Intergovernmental Panel on Climate Change (IPCC), "the evidence suggests that outcomes seen as equitable can lead to more effective cooperation." (IPCC 2014)

However, this is not just true for countries, but can also apply to entities such as provinces, cities, or indeed, individuals – actors seen as freeriding, as not contributing their fair share, can undermine the effectiveness of the cooperation needed. This report focusses on the Province of Quebec and asks, "What is Quebec's fair share of global climate action in the next decade?" The report focusses on mitigation – reducing Quebec's greenhouse gas emissions in line with its fair share of the global mitigation effort – though "climate action" encompasses many more very important aspects, including adapting to the already changing climate in order to reduce risks from climate impacts; initiatives such as just transition for workers and communities impacted by efforts to reduce emissions, or adapt to climate change; reacting to the losses and damages caused by climate impacts; financial and other support for climate action in poorer countries; among others.

The Government of Quebec, although it is a federated State, has long played an active role in international climate politics. It was the first federated State to participate in international climate finance in 2015, a commitment which was renewed in the 2019-2020 budget, through support for its international climate cooperation program. Quebec is also, with California, an initiator of the Western Climate Initiative, which aims to create a North American cap and trade market for carbon emissions.

The Government of Quebec describes itself as a leader at the international level in the fight against climate change. To contribute to the global effort to reduce GHG emissions, Quebec has set a series of targets: 6% below 1990 levels for 2012 (target reached), 20% below 1990 levels for 2020, and 37.5% below 1990 levels for 2030. The Government of Quebec has also signed a Subnational Global Climate Leadership Memorandum of Understanding (Under 2 MOU) which signals the intention of states and regions to contribute to reducing emissions to by 80% to 95% of emissions by 2050.

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The Government of Quebec has joined international coalitions and initiatives as a way to contribute to the global effort to respond to the climate crisis. The *Ministère de l'Environnement et lutte contre les changements climatiques* reports that these coalitions and initiatives include the Under 2 Coalition, the Network of Regional Governments for Sustainable Development (Quebec was the first North American jurisdiction to join, MRIF 2010), and International Alliance to Combat Ocean Acidification (MELCC 2016). It has also created the International Climate Cooperation Program, an award-winning program aiming to support the most vulnerable francophone countries (MELCC 2019).

All this makes clear that Quebec is considering climate change to be an important challenge for humanity and that both domestic action and international cooperation is needed to address this challenge, and that Quebec is willing to proceed with such action and cooperation independently of the Canadian federal approach to climate change. In the context of international cooperation, the question arises of how much each actor should be expected to contribute to that cooperation, or, in other words, what is each actor's fair share. This report is intended to shed light on this question by presenting results of effort-sharing calculations for the Province of Quebec that are firmly based on the best available science and the ethical principles agreed to by all countries in the United Nations Framework Convention on Climate Change.

In this current moment which is very much defined by the global coronavirus pandemic, the issue of solidarity and collaboration in the face of a very severe threat and the profound interconnectedness between actions of people across time and space has come to the forefront. The are many parallels and many structural similarities between the fight against the coronavirus outbreak and the fight against climate disaster. In both cases, societies face fundamental choices in responding to the threat, in both cases there are profoundly different alternatives for a response: We can resort to nationalist, individualist responses, with the richest and most powerful countries and people taking care of themselves, and leaving the others to fend for themselves. Or, we can decide that solidarity and investment in the commonwealth is the best, probably only, way through the coronavirus crisis. For the climate crisis, we have essentially the same choice. Do the wealthy countries and people continue indefinitely to drag our heels on cutting emissions to protect the global commons, while building walls and letting the private sector sell adaptation services to the highest bidders? Or do we cooperate in a fair way, preserve the global climate, invest in broadly accessible adaptation, address the needs of the vulnerable in our own countries and elsewhere?

Writing in the Financial Times in March, Yuval Harari (2020) calls the coronavirus pandemic "perhaps the biggest crisis of our generation," a title previously routinely applied to the climate crisis:

> “ *Humanity needs to make a choice. Will we travel down the route of disunity, or will we adopt the path of global solidarity? If we choose disunity, this will not only prolong the crisis, but will probably result in even worse catastrophes in the future. If we choose global solidarity, it will be a victory not only against the coronavirus, but against all future epidemics and crises that might assail humankind in the 21st century.* ”

Global solidarity, however, can best flourish in an environment of trust, and trust requires an understanding that everybody is contribution to the collective effort to stem the crisis, be it social distancing and mask-wearing in the case of the coronavirus crisis, or contributing a fair-share effort to the global mitigation effort in order to avert the worst climate impacts.

Global Mitigation Effort

In order to establish Quebec's fair share of a global mitigation effort, this global mitigation effort has to be defined first. The relevant goal of mitigation is defined by the Paris Agreement as "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C" (UNFCCC 2015, Article 2.1.a). While Quebec is not a state party to the Paris Agreement, Canada is, and the Paris Agreement and its goals have broad political support in Quebec. Mandated by the Paris Climate Conference, the IPCC released a Special Report on the science of 1.5°C in late 2018, which represents the best available science with regards to determining the global mitigation effort associated with the 1.5°C Paris Agreement warming limitation goal.

However, the IPCC report summarizes a large number of different future mitigation scenarios that have been produced by scientists and that reflect a large and diverse set of assumptions made by these researchers. The IPCC report merely summarizes and categorizes these scenarios, it does not make judgements with regards to the plausibility, or social, political or ethical acceptability of these assumptions, or their broader implications. For example, many of the 1.5°C scenarios imply an "overshoot," where temperatures temporarily exceed 1.5°C before coming back down to 1.5°C or below. Many of the scenarios also envision the large-scale use of "negative emissions technologies" (NETs), also known as "carbon dioxide removal" (CDR), which might not be available at the scale assumed and/or carry substantial risks and side effect that make them socially undesirable. (for more detail on CDR and overshoot, see annex 1)

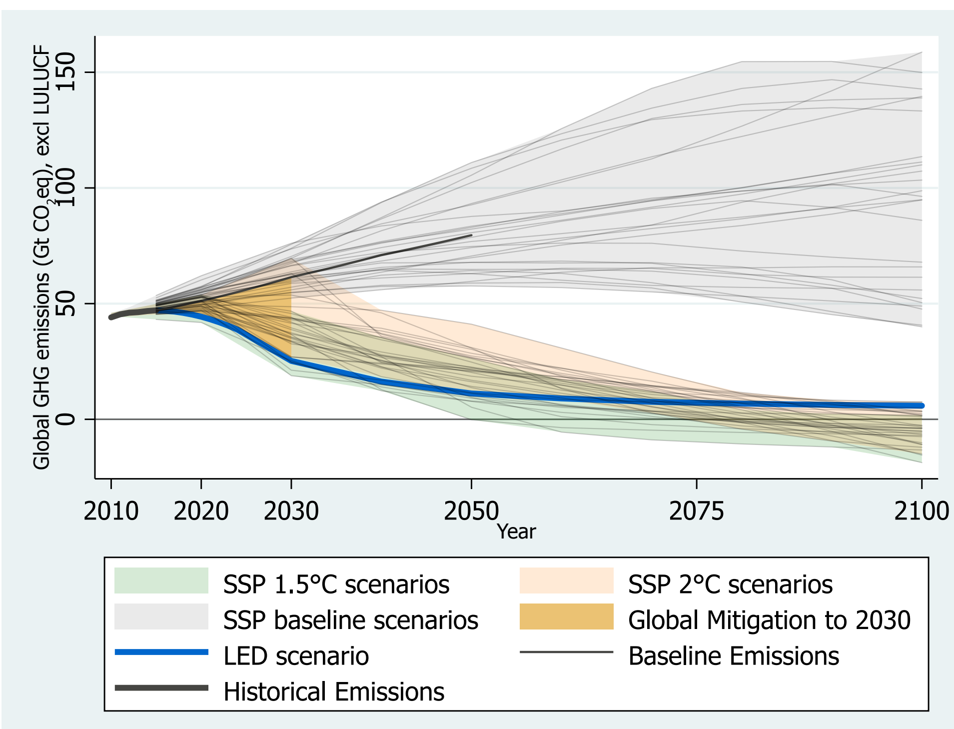


Figure 1. LED Pathway (blue), showing emissions rapidly peaking globally (by 2020), declining 80 % by 2050 and toward zero by the century's end; and the baseline emissions projections used in this study (black solid line to 2050), both in the context of the 1.5°C consistent scenarios (N=13, green area) of recent SSP studies (Rogelj et al. 2018), as well as 2 °C consistent pathways (N=19, pale red area) and baseline projections (N=26, grey area) of the mainstream SSP models (IIASA 2016). The figure also shows the possible range of emissions resulting from current climate action pledges (NDCs) under the Paris Agreement (black boxes).

For this reason, this report follows the example of similar fair shares reports (e.g., CSO Equity Review 2018; Kartha et al. 2018; CAN-Rac Canada 2019; Holz 2019; Christian Aid et al. 2020) and applies the precautionary principle to the determination of the total global effort, selecting the "Low Energy Demand" (LED) scenario (Grübler et al. 2018) as the relevant global mitigation pathway. The LED scenario avoids the use of CDR, has no overshoot,[1] and takes as a central scenario design criterion the universal attainment of a "decent living standard" and access to the associated energy services. (see annex 2 for more details on the LED).

Figure 1 shows the LED pathway in the context of other 1.5°C (green) and 2°C (pale red) consistent mitigation pathways as well as baseline scenarios (grey) modelled in the context of the Shared Socio-Economic Pathways (SSP) initiative. Compared to most other of these scenarios, it features a more stringent near-term emissions reductions trajectory and a flatter curve later in the century, with low residual emissions, mainly from agriculture, through the end of the century. Note though, that the chart, like the rest of this report, excludes emissions and removals from Land Use, Land Use Change and Forestry (LULUCF).[2] If those figures were included, they would be shown to offset the residual CO_2 emissions in the LED pathway and CO_2 emissions to go net negative as well from the 2050s. In Figure 1, the orange wedge shows the mitigation through 2030 required between the baseline scenario and the LED mitigation pathway. The black blocks in 2025 and 2030 show the emissions range that is implied by the mitigation pledges (or "Nationally Determined Contributions," NDCs, in UN climate change jargon) that have been made by countries in the context of the Paris Agreement.

Under this pathway, global emissions would fall to about 25 billion tons of carbon dioxide equivalents ($GtCO_2eq$) in 2030. Figure 1 and Figure 2a show how achieving an emissions level of 25 $GtCO_2eq$ in 2030 would compare to current emission levels and a baseline reference case for future emissions if no mitigation were undertaken (orange wedge). As shown in these figures, achieving the LED scenario, would see global emissions being reduced by 36 $GtCO_2eq$, which is more than 50% relative to the assumed baseline emissions in that year (approx. 61.5 $GtCO_2eq$).

1 Strictly speaking, it does have an overshoot and is thus considered a "low overshoot" scenario in the IPCC report, since its temperature increase peaks at 1.52°C before going back to below 1.5°C. However, it is questionable whether the models to estimate the warming impact of scenarios are precise enough to support two decimals of precision, which suggests that rounding to 1.5°C is appropriate.

2 LULUCF emissions are excluded here for a variety of reasons. First, LULUCF emissions data is subject to very large data uncertainties, especially at the national level. There is no authoritative source of national-level time series data on removals and emissions from the LULUCF sector that has a sufficient level of certainty for being suitable for global fair shares calculations. Furthermore, and relatedly, wealthy countries including Canada, have negotiated accounting rules under the UNFCCC for accounting of LULUCF emissions that do not reflect the emissions and removals that are actually occurring and may allow countries to report carbon credits from the LULUCF sector even though substantial emissions occurred (Greenglass et al. 2010; Holz 2012, 2015). Thus, the available data on LULUCF emissions does not lend itself for a robust framework of global fair shares calculations.
A second reason is that, even with accurate data and accounting, a strict fungibility between land-based carbon on one hand and fossil carbon on the other hand is deeply problematic, in that it falsely equates the scope for labile, limited, and multi-purpose stock of carbon on the land to substitute for the permanent and secure stock of fossil carbon deep underground. Third, the extremely close link between land use and other sustainability and human rights concerns suggests that land must be managed within a substantively different type of regime than the UNFCCC, one that focuses on indigenous rights, biodiversity, food security, human rights, watershed protection, etc. lest it risk seriously undermining these other objectives.
Importantly, this is not to suggest that action on land-related emissions is unimportant or does not warrant science- and equity-based assessment, but rather to argue that such actions should be placed in their own holistic context.

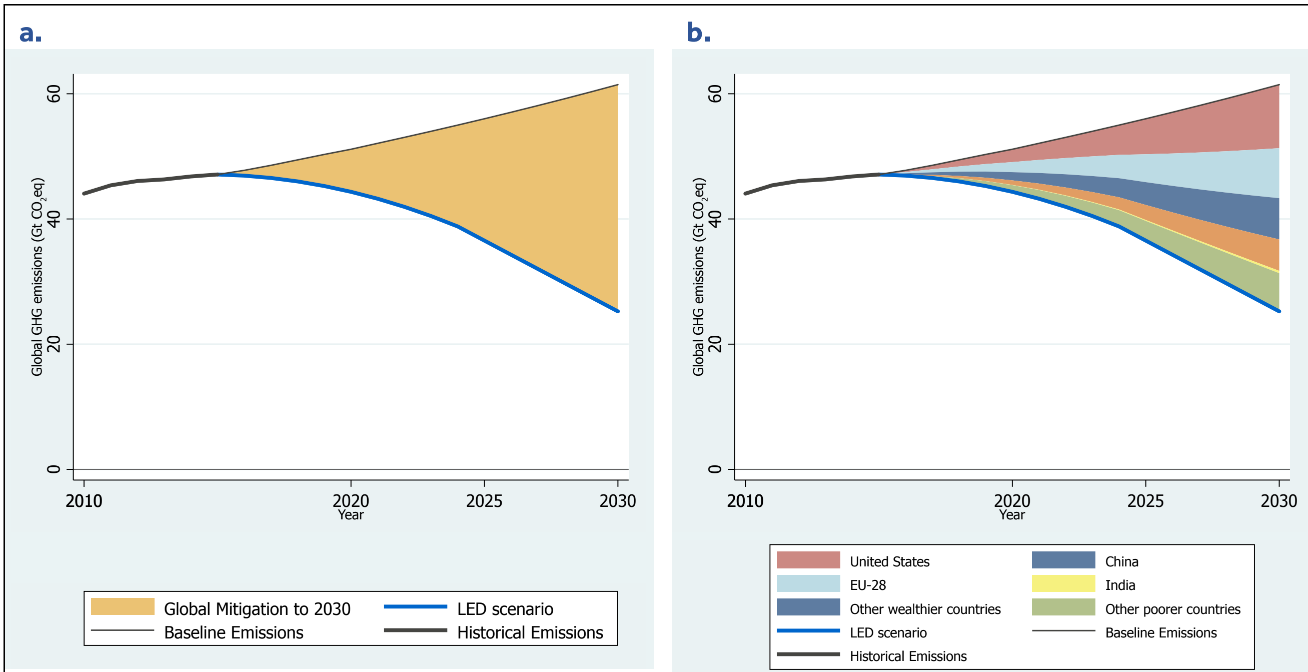


Figure 2: a. LED Pathway and baseline , showing necessary global mitigation (orange shading). b. LED Pathway and baseline, showing necessary global mitigation divided into illustrative national shares of the selected countries and groups

From Global Effort to Quebec Fair Share

The global effort of reducing emissions – as displayed as the orange shading in Figure 1 and 2a – can be divided among all countries (or subnational entities within those countries) according to their responsibility (for causing the problem) and capacity (to help deal with it), as shown in Figure 2b, corresponding to what could be considered their fair share for implementing the global mitigation effort required to achieve the LED pathway's trajectory.

This approach reflects core long-standing equity principles in the United Framework Convention on Climate Change (UNFCCC). They were summed up nicely by Al Gore in a *New York Times* op-ed on climate change in the run-up to the Copenhagen climate negotiations in 2009 (Gore 2007):

> “ *Countries will be asked to meet different requirements based upon their historical share or contribution to the problem and their relative ability to carry the burden of change. This precedent is well established in international law, and there is no other way to do it.* ”

Here, we translate *capacity* and *responsibility* to GHG emissions pledges using a straight-forward approach developed and applied by the Civil Society Equity Review (CSER) Coalition, a coalition of more than 200 groups[3] spanning the global North and

3 Quebec signatories of the CSER reports include Association québécoise de lutte contre la pollution atmosphérique (AQLPA) and ENvironnement JEUnesse as well as many Canadian national organizations with presence or members in Quebec, such as David Suzuki Foundation, or Climate Action Network Canada -Réseau action climat Canada.

South and multiple perspectives (CSO Equity Review 2015, 2017, 2018). In that approach, capacity is based on national income, and responsibility is represented by cumulative historic GHG emissions. The CSER coalition defined these in modestly progressive terms (akin to a progressive tax), reasoning that it would not be fair to treat a rich person's millionth dollar of income the same as a poor person's first dollar. While this approach does not propose to actually implement an additional tax on personal incomes, the concept of thinking about a country's or province's capacity follows an approach similar to the one taken, for example, by the Québec income tax: The Québec income tax system leaves the personal amount of up to $15,269 tax-free, while the highest incomes of over $106,555 are subject to a 25.75% marginal provincial income tax rate[4] (values for 2019; see Revenu Québec 2020). (also see annex 3 for details on how capacity and responsibility if defined in the effort sharing approach used here)

In the CSER approach, capacity was calculated in a modestly progressive way by excluding the first USD $20/day of income contributed to the nation's GDP per person when considering that nation's economic capacity to act on climate change ("medium progressivity" in the charts and tables below). Analogously, Responsibility was calculated by exempting greenhouse gas emissions from consumption corresponding to income up to the first $20/day per person. The CSER coalition also calculated a somewhat more progressive fair share, where income above a threshold of USD $50,000 per year per person was considered more heavily than income below that threshold ("high progressivity"). For this report, an additional group of benchmarks ("low progressivity") is included for illustrative purposes, where the exempt amount is lowered to a mere USD $2,500 per person, representing a subsistence threshold or substantial poverty. This benchmark is also used in the CSER approach, but highlighted as inequitable in the views of the organizations of the CSER since it would shift much of the burden of climate action from the world's richest to the poorest.

Benchmarks are also different with regards to the date from which they take historical emissions into account. Here, results for historical responsibility start dates of 1850, 1950 and 1990 are reported.[5] As a general rule, the closer to the present date the consideration of historical emissions starts, the more favourable the outcomes become for the wealthier countries, which tend to have emitted longer and at historically higher rates.

Importantly, the general effort sharing approach used here takes the individual as its basic conceptual unit of analysis – which means that a rich person with a large personal carbon footprint living in a poor country with overall low emissions has the same personal fair share as another equally rich person with a similarly large personal footprint living in a wealthy county. Countries' (or, here, provinces') fair shares are then conceptualized as the sum of the personal fair shares of their residents. Thus, countries (or provinces) with comparatively more income-rich people with larger carbon footprints will

4 Those figures are for Quebec income tax only. If combined with the federal income tax figures, the tax-free threshold decreases to $12,069. Hence, the federal income tax system can be said to be less progressive for lower incomes, because it asks individuals earning above $12,069 to contribute more than the Quebec tax code would. On the other hand, the marginal federal tax rates for the highest earners keep increasing above the highest threshold in the Quebec code, with incomes above $214,368 being subject to a marginal federal tax rate of 33% (or combined with Quebec: 58.75%). This makes the federal system more progressive for higher incomes compared to the Quebec code, since higher earners are expected to contribute an increasing fraction of their incomes for financing public goods via their taxes.

5 Importantly, it was somewhat difficult to source reliable, high resolution data sources for emissions, population, and GDP on province level for the periods before 1990, 1981, and 1971, respectively. While substantial efforts have been made to estimate these data using proxy data sources and other estimation approaches, the further back from 1990 the lower the certainty of the province level breakdown of Canadian totals. See annex 5 for details on sourcing and estimation of province level data series.

have larger national fair shares than those with more poorer people with lower emissions.

For the purpose of this technical report, which is intended to facilitate discussions among Quebec civil society with regards to the appropriate interpretation of what would constitute fairness with regards to Quebec's contributions, a larger selection of possible calculations of fair shares is presented below for the province of Quebec (Figure 3 and Table 1; see annex 4 for equivalent charts for other Canadian provinces).

In addition to the combinations of the historical responsibility start dates and progressivity settings mentioned above, three additional benchmarks are presented in Table 1 and Figure 3 which disregard responsibility for creating the climate crisis, via historical emissions of GHGs, and instead only considers countries' capacity to act on solving that crisis, under various conceptualizations of progressivity. Such a position could be ethically justified with considerations from the transitional justice tradition of moral philosophy, which often argues for refraining from holding perpetrators of historical injustices materially responsible for their past injustices and instead focusses on symbolic acknowledgement and responsibility, healing and implementation of changes to ensure a non-repetition of the damaging past practices. In the case of fairly sharing the global mitigation effort among the worlds' populations, this approach would focus on the question of how they can contribute to the solution, rather than how they contributed to the problem.

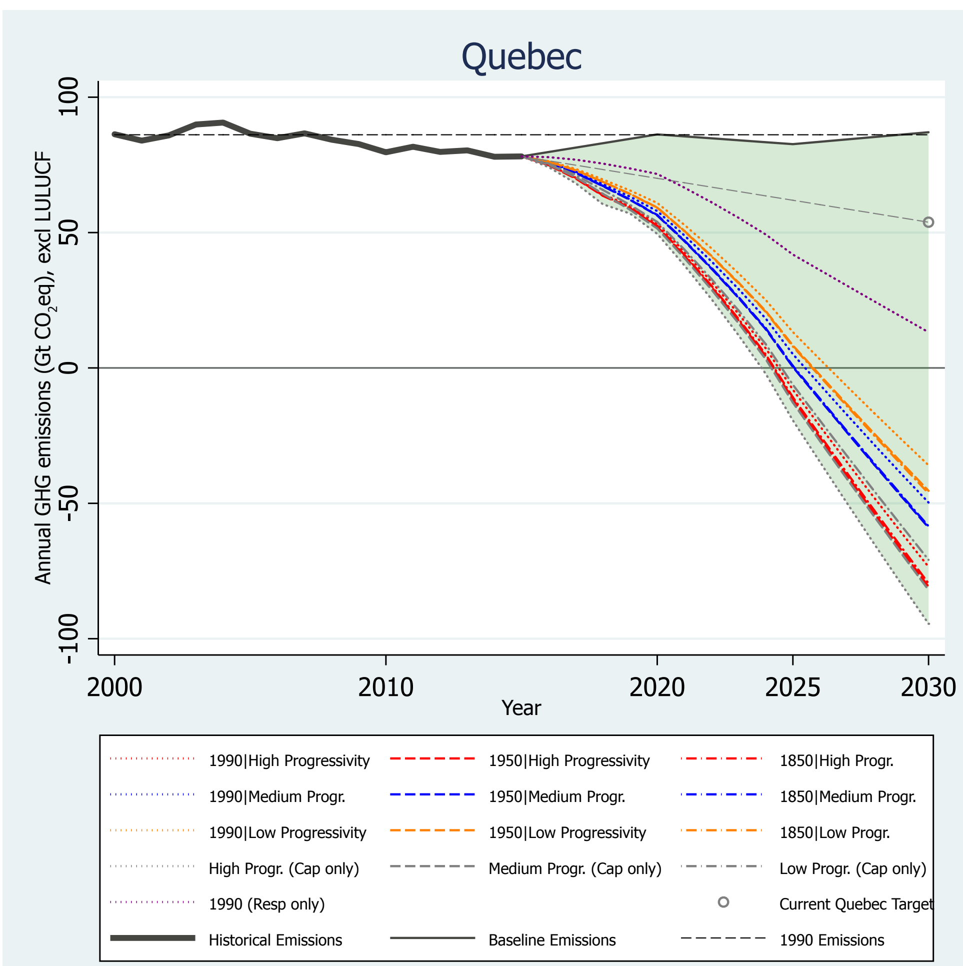


Figure 3. Illustrative benchmark emissions trajectories reflecting different possible views of how to conceptualize a fair share for Quebec. Historical emissions, baseline emissions and current Quebec government target shown for reference. Also shown (purple dotted line) is a benchmark that only considers historical responsibility (but not capacity) since 1990.

Finally, considering the political salience of the year 1990 as a reference year for emissions reductions in Quebec, an illustrative benchmark is also shown that only considers historical responsibility for creating the climate crisis (i.e. it disregards nations' financial capacity to help solve it) and only considers that responsibility since 1990. Such benchmarks have routinely been dismissed as unfair to poorer countries and populations (CSO Equity Review 2015). This is because on one hand, the date of 1990 is considered too recent as a fair reference point because "the large volume of historical emissions from which many countries benefited during the decades of unrestricted high-carbon development prior to the UN Convention cannot be ignored from both a moral and legal standpoint" (CSO Equity Review 2015, p. 2). On the other hand, the consideration of financial capacity is important to ensure that the world's poorest are not unduly burdened with the effort to address the climate crisis all the while they are still struggling to secure dignified lives free of poverty.

The Climate Equity Reference Calculator used here (Holz et al. 2019; Kemp-Benedict et al. 2017)[6] supports additional ways of setting fair shares benchmarks that could be explored than those depicted here. For example, the calculator can be used to calculate fair shares consistent with an ethical position that considers it fair that in addition to exempting income below a certain lower threshold (e.g. $20 per person per day) from counting towards a country's or province's capacity to address climate change, it would be appropriate to more heavily consider incomes above a certain upper threshold as available to address climate change, for example by applying a multiplier (say, 5x) to incomes above such a threshold (say, $100,000 per person per year).

Based on these benchmarks, responsibility and capacity are calculated for each country (or, in the case of Canada, each province) over time, and each country's or province's fair share of the global mitigation effort in each year is determined by its share of global responsibility and capacity (averaged together). For Quebec, the share comes to between 0.38% and 0.46% of the total global mitigation effort (when excluding the arguably inequitable "low progressivity" group of benchmarks and the benchmarks that ignore historical responsibility altogether), compared to Quebec's share of only 0.11% of the global population. This is roughly 137 to 168 $MtCO_2eq$ of the 36 $GtCO_2eq$ total emissions reduction required globally below baseline in 2030,

Quebec

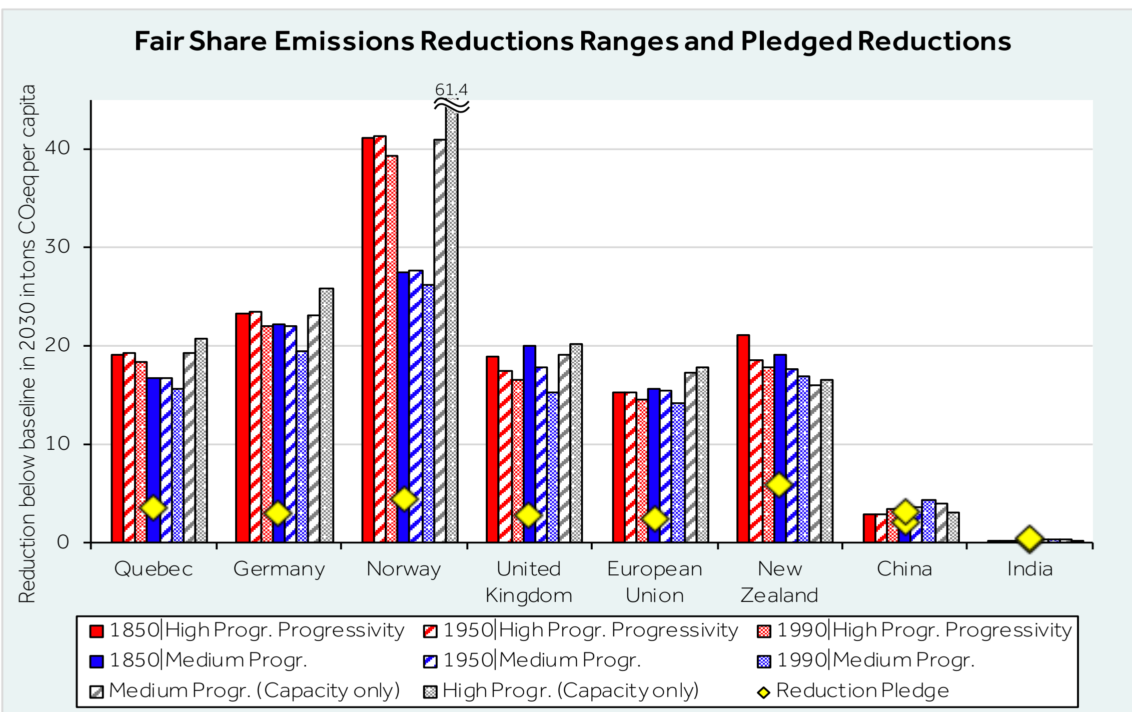
Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	Reductions in 2030 below 1990 levels %
Benchmarks considering Capacity and Responsibility					
Low	1850	0.37%	133.4	132.4	153.8%
	1950	0.37%	132.5	131.5	152.7%
	1990	0.34%	123.0	122.1	141.7%
Medium	1850	0.40%	145.5	144.6	167.9%
	1950	0.40%	146.0	145.1	168.4%
	1990	0.38%	136.8	135.8	157.7%
High	1850	0.46%	166.6	165.7	192.4%
	1950	0.46%	167.8	166.9	193.8%
	1990	0.44%	160.5	159.6	185.3%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.44%	157.9	157.0	182.3%
Medium	not considered	0.47%	169.0	168.1	195.2%
High	not considered	0.50%	181.6	180.6	209.7%

Table 1. Emissions Reductions in 2030 for the illustrative benchmarks from Figure 3, as emission reductions below baseline and 1990 emissions levels, each depending on the degree of progressivity in treating national income (Low, Medium, High) and the approach for considering historical emissions (1990, 1950, or 1850 start date, or disregarding historical emissions altogether).

6 The interactive calculator can be accessed at https://calculator.climateequityreference.org. Note that the calculator database used for province level calculations is not available in the standard instance of the calculator. Please contact the author for instructions on how to use the calculator interactively for province level explorations.

which is 136 to 167 $MtCO_2eq$, or 158% to 194%, below 1990 levels. The results of Figure 3 and Table 1 also show that, while the extend of the Quebec fair share is somewhat sensitive to the specific choices made when establishing each benchmark, the results are also fairly consistent across benchmarks, especially when only considering the six "high progressivity" (red) and "medium progressivity" (blue) benchmarks. Crucially, however, it is also apparent, that regardless of the specific choices with regards to how to conceptualize Quebec's fair share, that fair share far exceeds (by 4 to 5 times) the provincial government's current target of 37.5% below 1990 levels by 2030. This remains true even when considering the illustrative "1990 (Responsibility only)" benchmark that is included in Figure 3 for reference. Even when completely disregarding nations' capacity for addressing climate change and when completely disregarding the emissions released prior to 1990, Quebec's share of the global effort would still be substantially larger (requiring a 85% reduction below 1990 levels) than the current government target - even though that could be seen as unfairly low, considering the reasons cited above for rejecting this benchmark as inequitable.

Conceptualizing fair shares in specific ways that lend themselves to quantification, also facilitates comparison between the fair-shares ranges and the emissions reduction pledges across jurisdictions. Figure 4 and the associated table shows the fair share ranges (the bars in the chart) for the specific benchmarks shown in Figure 3 and Table 1 (excluding the "low progressivity" benchmarks). The chart and table also show the emissions reduction targets for



		Quebec	Germany	Norway	United Kingdom	European Union	New Zealand	China	India
Fair Share Range	Low	15.7	19.5	26.2	15.3	14.2	16.1	2.9	0.03
	High	20.8	25.8	61.4	20.1	17.7	21.1	4.3	0.36
Pledge		3.6	3.0	4.4	2.7	2.5	5.9	2.0 to 3.2	0.19 to 0.33

Figure 4 and Table 2. Fair share ranges and pledged emissions reductions (both expressed as emissions reductions per capita below no-effort baseline in 2030) for selected economies.

2030 that the countries have committed themselves to.[7] In order to enable direct comparison between nations of vastly different population sizes, emissions reductions (both fair share benchmarks and pledges) are shown in per-capita terms, as per-capita emissions reductions below no-effort baseline projection in 2030.

Comparing the fair shares ranges of the economies shown in the chart, Quebec has similar fair shares as the other developed nations shown, with the UK and the EU as a whole tending to have slightly smaller fair shares (depending on the specific benchmark) and Germany and Norway somewhat or substantially larger fair shares, respectively. This is perhaps not surprising given that these countries share Quebec in terms of being fairly wealthy and having a substantial historical responsibility. China and India, on the other hand, have substantially smaller per capita fair shares, owing to their comparatively poorer population and smaller historical and current per-person carbon footprint. It is important to note, though, that even though their fair share is smaller, and in the case of India, much smaller, than those of the developed economies, they do have their own fair share which they can justifiably be expected to implement in their own country with their own resources. This is due to the capacity and responsibility of the growing economic middle and upper classes in these countries.

Figure 4 also facilitates the comparison of the actually committed emissions reductions of these nations. Norway and New Zealand have committed to a higher per-capita emissions reduction than Quebec, the other countries to lower ones. However, the arguably most appropriate way to compare emissions reductions pledges across nations is not in terms or absolute or per-capita emissions reductions, but in terms of the fraction of a nation's fair share that the pledged reduction represents. For Quebec, depending on the specific fair-shares benchmark, the current government target represents between 17 and 23% of the fair share and the other developed countries in the chart have similar results. The developing countries in the chart, on the other hand, have pledged at least about half of their fair share (if comparing the less ambitious end of their pledge range with the most demanding end of their fair-shares range) but could also have pledged as much as 110% (China) or 11 times (India) their fair share in the case of the more ambitious end of their pledge range compared to the less demanding fair-shares benchmark.

Implementing Quebec's Fair Share

While 137-168 $MtCO_2eq$ of emission reduction in 2030 below baseline is Quebec's fair share of the global effort, it could not practically be undertaken within Quebec, as it exceeds total domestic emissions in Quebec, which is currently about 86 $MtCO_2eq$. It is not surprising that Quebec's fair share of the necessary global mitigation is greater than its current share of global emissions. After all, Quebec has been substantially contributing GHGs for well more than a century, and – not unrelatedly – is among the wealthier economies of the world.

Quebec's fair share of the required global mitigation effort under various benchmarks is pictured in Figure

7 For Quebec, the current provincial government target is shown. For Germany, the modelled emissions reductions resulting from the EU's mitigation pledge under the UNFCCC is shown (see footnote 10 in Kartha et al. 2018 for methodological details). For the UK, the emissions reductions resulting from the 5th UK carbon budget are shown. For Norway, China and India, the projected emissions reductions resulting from the mitigation pledge under the Paris Agreement are shown. Note that for India and China, the reductions are shown as a range because these countries have communicated a target range. Values for all countries are taken from the Climate Equity Reference Calculator (Kemp-Benedict et al. 2017), except India's which is from the 2018 CSO Equity Review report (CSO Equity Review 2018).

3 as if it was carried out domestically, which would require Quebec emissions to plummet to zero well around 2025 (depending on the specific benchmark) and continue to rapidly become increasingly negative thereafter. Clearly, it would be wholly unrealistic for Quebec to achieve this fair share through domestic reductions alone. However, even if Quebec were to completely eliminate domestic emissions (i.e. reduce emissions to zero), the additional effort required to fulfill Quebec's fair share amounts to *well more than a third to nearly half* of Quebec's fair share by 2030. Therefore, it cannot be neglected if Quebec is to be seen as carrying its weight in the global effort to combat climate change.

The finding that the fair shares reduction target as derived from ethical principles is in excess of 100% is a typical result for principle-based fair shares calculations for wealthy economy with a large per-capita share of the historical emissions like Quebec.

Obviously, it is *physically* impossible to implement this fair-shares reduction, for all of which Quebec can be said to be *morally* responsible, within Quebec. This is because this fair share obligation exceeds any plausible interpretation of the total mitigation potential within Quebec. However, the reverse is the case for most developing countries: those countries' mitigation potential exceeds, often very substantially, the amount of mitigation that can be fairly expected to be implemented by those countries. Nonetheless (and this is one of the fundamental, yet unavoidable, injustices of the climate crisis), most of the mitigation potential of those countries needs to be implemented in order to avoid exceeding the 1.5°C warming limitation objective. Since it would not be fair to expect those countries to implement that potential with their own, limited, resources, it is appropriate for wealthy entities like Quebec to engage in international mitigation cooperation and support, e.g. via financing, capacity building or transfer of technologies, to ensure the availability of resources required to implement that fraction of the mitigation potential of developing countries that exceeds those countries' own fair share obligation. It is through this international support that Quebec, Canada and other wealthy nations can discharge that fraction of their total fair shares contribution that exceeds their own domestic mitigation potential. In the case of Quebec, which is not a state party to the UN climate convention, a practical question emerges on how this can be best implemented. Quebec already has for many years directly contributed to some of the funds under the UNFCCC that are directly supporting climate action in developing countries (including the Least Developed Countries Fund and the Adaptation Fund), so there is already an established precedent of Quebec engaging directly in international cooperation on climate change independent of Canadian federal government initiatives. This could be further deepened and broadened, to include direct bilateral cooperation with countries or sub-national entities in developing countries.

However, whether this international support component of Quebec's fair share is directly discharged via cooperation of Quebec with jurisdictions in the developing world or through international funds, or contributions made by Quebec to Canada's international cooperation initiatives, is secondary. Irrespective of those "delivery details," the contributions in question are those of Quebec's people and the Quebec economy, and in order to Quebec to contribute its full fair share to the global effort, Quebec needs to ensure such initiatives are implemented at scale.

In order to be able to determine which fraction of the total fair-shares reduction target, as derived from ethical principles, should be implemented through domestic mitigation and which fraction through international cooperation and support, an estimate of the domestic mitigation potential is required. Ideally, such an estimate would be based on a detailed socio-techno-economic analysis of the mitigation potential under the most ambitious assumptions. However, at this point, such analysis is not available for Quebec, though socio-economic analyses exist that examine approaches in which to achieve the current Quebec government target of 37.5% below 1990 levels by 2030 (Dunsky et al. 2019) – the models used in these analyses could potentially be utilized with substantially different sets of assumptions to establish the most ambitious mitigation trajectory possible.

Meanwhile, in the absence of this analysis and its results, illustrative figures can be derived from similar efforts for Canada, or from the global figures of the pathways summarized by the IPCC.

First, Climate Action Network Canada – Réseau action climat Canada (CAN-Rac) and several of its members carried out an analysis of potential mitigation policies and measures that should be implemented in Canada and of the potential emissions reductions impact of these measures. This analysis (CAN-Rac Canada et al. 2019) concluded that sufficient mitigation potential exists to reduce emissions in Canada by at least 60% below 2005 levels while ensuring meaningful engagement of Indigenous People, promoting just transitions for workers and communities hitherto dependent on the fossil fuel industry or other carbon-intensive activities, and enhancing transparency and accountability for the overall mitigation program carried out. Assuming that Quebec mitigation potential is roughly equivalent to the Canadian average, the results of that analysis would correspond to reductions of roughly 53 $MtCO_2eq$, or 60.1%, below 1990 levels.

Secondly, the global mitigation pathway utilized to define the global mitigation effort for the fair shares analysis in this report, the LED pathway, requires global emissions reductions in 2030 of 51% below 2020 levels. Applying this reduction to Quebec translates to 52.7%, or 55.1 $MtCO_2eq$ reductions below 1990 levels. Looking at the LED pathways reductions as relative to "no effort" baseline projections,[8] rather than fixed 2020 emissions levels, reveals a reduction of 59% below baseline levels in

Source	Type	2030 Reduction	Equivalent Quebec Reduction below 1990 levels	
			%	Mt CO_2eq
LED Pathway	Global Average	51% below 2020 levels	52.7%	46.9
	Global Average	59% below 2030 baseline	59.9%	53.4
UNEP Emissions Gap Report 2019	Global Average	55% below 2018 levels	57.5%	51.2
	Global Average	61% below baseline	61.8%	55.0
IPCC Special Report on 1.5°C (Median of No and Low 1.5°C Overshoot Scenarios)	Global Average	48% below 2020 levels	49.8%	44.3
	Global Average	61% below 2030 baseline	61.9%	55.1
IPCC Special Report on 1.5°C (Third Quartile of No and Low 1.5°C Overshoot Scenarios)	Global Average	63% below 2020 levels	64.3%	57.2
	Global Average	81% below 2030 baseline	81.4%	72.5
CAN-Rac Canada	Canadian Average	60% below 2005 levels	60.1%	53.5

Table 3. Illustrative equivalent emissions reductions in Quebec under application of global or Canadian average emissions reductions from selected sources.

8 "No effort baseline" (or simply "baseline") projections in the calculations of this section are those from the Climate Equity Reference Calculator unless otherwise specified.

2030, which, if applied to Quebec, translates to 59.9%, or 46.9 $MtCO_2eq$ below 1990 levels by 2030.

Thirdly, the United Nations Environment Programme (UNEP) publishes a regular "Emissions Gap Report" (UNEP 2019) that contrasts baseline projections and pledged emissions reductions of countries, sub-national governments and companies with the required emissions trajectories to achieve the well-below-2°C and 1.5°C temperature limitations objectives. According to that report, 2030 emissions in the 1.5°C consistent scenarios are 55% below 2018 levels (and 61% below the "2005-Policies" baseline), which, if applied to Quebec's 2018 emissions (or baseline), results in an 2030 emissions reduction of 51.2 $MtCO_2eq$ or 55 $MtCO_2eq$ below 1990, respectively (a 57.5% or 61.8% reduction below 1990 levels).

Finally, the IPCC's Special Report on 1.5°C highlights results for the group of "pathways with no or limited overshoot of 1.5°C" and reports that the median emissions reductions of these pathways in 2030 is about 45% below 2010 levels, with the third quartile of the 2030 emissions reductions across scenarios being 60% below 2010 levels (IPCC 2018, Summary for Policy Makers, Sentence C1). This is an important finding, however it is crucial to highlight that the choice of 2010 as the reference year for these statements is largely arbitrary and is based on the fact that 2010 was the last year in which the historical emissions data for most scenarios (many of which only report data in decadal intervals) were roughly equivalent, thus making 2010 the most recent common reference point across scenarios. However, when thinking about how to apply those global figures to individual countries, it is important to remember that different countries have had substantially different emissions trajectories since 2010 and fixing reduction figures to arbitrary reference years in the past typically results in a bias against developing countries many of which still have very low per-capita emissions and an upward trajectory of emissions. This systematic bias against developing countries is stronger, the further in the past the arbitrary reference year is set; which makes, for example 1990 an inappropriate choice of reference year for comparing ambition across jurisdictions.[9] The Paris Agreement acknowledges this dynamic, "recognizing that peaking will take longer for developing country Parties." Hence, it makes sense to look beyond the summary figures from the IPCC report and directly utilize the underlying scenario data upon which the IPCC's conclusions are based, via the Special Report's scenario database (Huppmann et al. 2018). This approach reveals that the median 45% below 2010 levels for the "no or limited overshoot" scenarios is equivalent to 48% below 2020 levels or 61% below baseline projections in 2030. For the third quartile (global reduction of 60% below 2010 in 2030), the equivalent is 63% below 2020 levels or 81% below baseline in 2030. Again, applying these figures to Quebec yields reductions of 49.8% (44.3 $MtCO_2eq$) or 61.9% (55.1 $MtCO_2eq$) below 1990 levels in 2030, respectively, for the median. And 64.3% (57.2 $MtCO_2eq$) or 81.4% (72.5 $MtCO_2eq$) below 1990 levels in 2030, for the third quartile.

With regards to simply applying the global average figures from the LED pathway or the no or low overshoot scenarios of the IPCC scenario database to Quebec, it is important to underline that these are global average figures and that it is generally accepted that developed countries should take the lead in reducing emissions earlier and more stringently than developing countries. Thus, a developed country jurisdiction such as Quebec

9 For example, imagine a hypothetical developing country A, which has very low per capita emissions of 1t/cap in 2010 and has doubled its emissions between 2010 and 2020 to 2t/cap, Imagine another, developed, country B, which had per capita emissions of 10t/cap in 2010 and managed to reduce them by 10% to 9t. For country A, a 45% reduction below 2010 levels would be a 72.5% reduction below current levels, while the same 45% below 2010 levels would only be a 38.9% reduction below current levels for country B. At the same time, with those emissions reductions, per capita emissions in country B (5.5t/cap) would remain substantially higher than those in country A (0.6t/cap) even though country A would have had made larger cuts in percentage terms of their current emissions.

ought to be contributing deeper cuts than the global average.

With that caveat, table 3 summarizes the figures discussed above. Depending on the reference year, the range for the two global data sources spans from 50% to 62% reductions below 1990 levels, though given the sequencing and stringency of emissions reductions in developed and developing countries, the Quebec reductions ought to be at least somewhat higher than the global average. Given that consideration as well as the fact that the Canadian source yields a 60% reduction below 1990 levels for Quebec, this 60% reduction will be used in the following for illustrative purposes.

Consequently, and recalling that Quebec's fair share has been previously calculated as 158% to 194%, below 1990 levels, the scale of the international mitigation cooperation that Quebec ought to engage should yield emissions reductions in developing countries by 2030 in the range of 98%-134% of Quebec's 1990 emissions. This, of course, would be in addition to Quebec's implementation of emissions reductions within the province of 60% of 1990 levels by 2030.

Figure 4 shows the total fair share of Quebec under various benchmarks as well as the domestic reduction as discussed above. For reference, it also shows the average of the six benchmarks used here and Quebec's 1990 emissions.

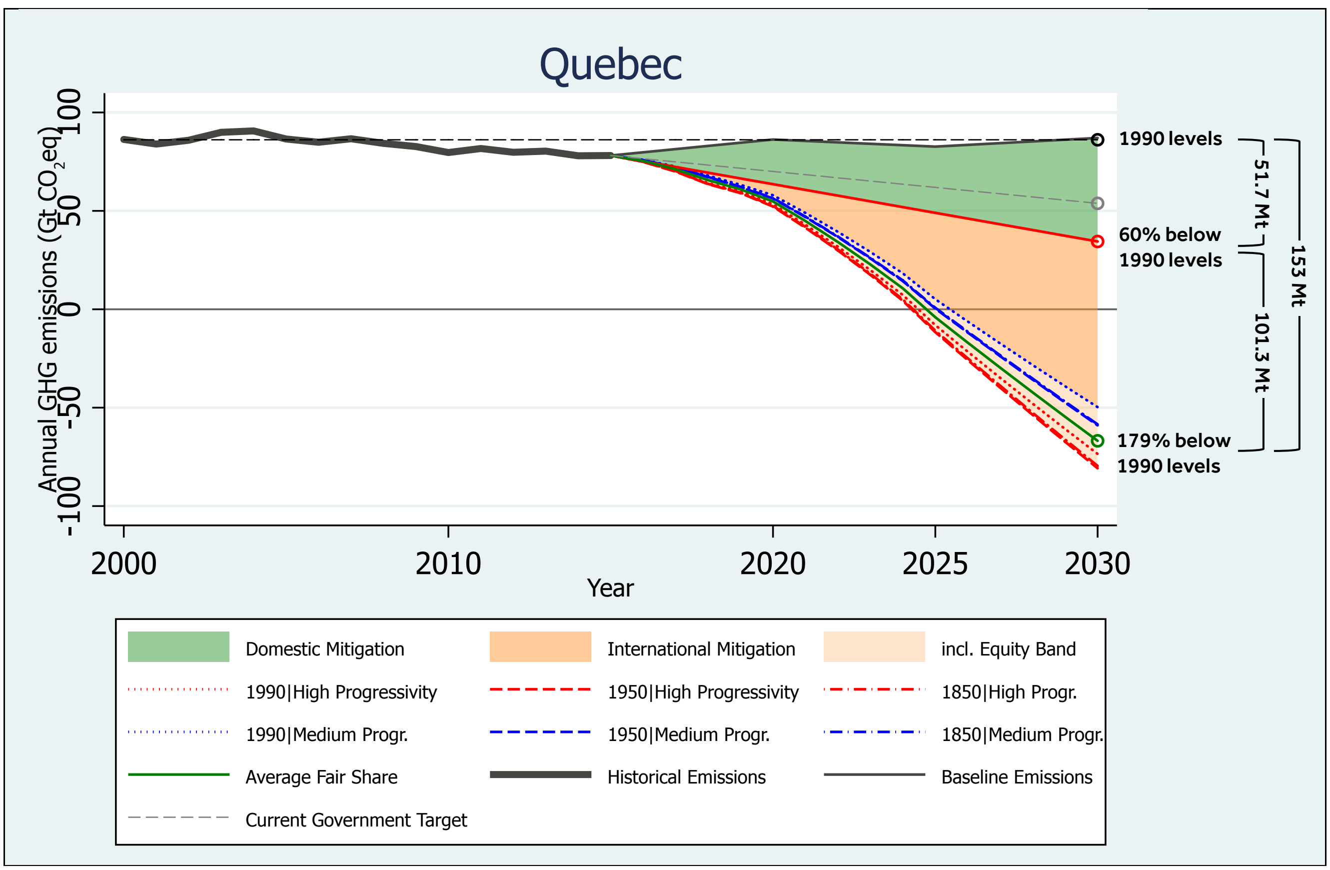


Figure 4. Quebec's Fair Share of the global mitigation effort implied by the LED global pathway, differentiated in a domestic mitigation component (green area) and an international support component (orange area), together constituting Quebec's total fair share (red and blue dashed/dotted lines), based on ethical principles of capacity, responsibility and need. The light orange area reflects the "equity band" – potential additional international mitigation support depending on specific benchmark chosen. The green line shows the average of all six fair shares benchmarks depicted here. The grey circular marker shows the current provincial target of 37.5% below 1990 levels and the dashed grey line a linear trajectory to that target.

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Annex 1. Negative Emissions Technologies and Overshoot

Source: Holz, C. (2018) *Modelling 1.5°C-Compliant Mitigation Scenarios Without Carbon Dioxide Removal*. Berlin: Heinrich Böll Foundation.
https://www.boell.de/sites/default/files/radical_realism_for_climate_justice_volume_44_8.pdf

"The majority of the 1.5°C-compatible emissions pathways in the climate modelling literature rely on removing large amounts of carbon dioxide (CO_2) from the atmosphere. This Carbon Dioxide Removal (or CDR) by large-scale technological means is typically focussed in the second half of the century and is typically modelled as Bioenergy combined with Carbon Capture and Storage (BECCS). BECCS means that CO_2 is removed from the atmosphere through photosynthesis of bioenergy crops, which are then used in bioenergy power plants or converted to liquid fuels, hydrogen or methane for the transport sector, while the associated emissions are partially captured and stored underground. The 1.5°C scenarios analyzed in Rogelj et al. (2015) envision cumulative removals between 450 and 1,000 $GtCO_2$ over the course of the century, with annual removals as high as 20 $GtCO_2$. Contrasting this figure with the current level of annual global emissions from fossil fuels, industry and land use change of about 31 $GtCO_2$ illustrates the scale.

More recently, scholars, policy-makers and civil society have increasingly questioned the feasibility of implementing CDR, especially BECCS, at this large scale, pointing to large land requirements for bioenergy crops, and the associated risks for food and water security or biodiversity, as well as technological feasibility, social and political acceptance issues, and storage permanence. In addition to BECCS, other CDR technologies have been proposed, such as biochar, soil carbon management, direct air capture (DAC), or enhanced weathering (EW). Other models include afforestation, where plantations of fast-growing trees are established on land that does not naturally support forest, in order to absorb and store CO_2 in these trees and soil.

Given the risks and uncertainties surrounding CDR, scholars have suggested to follow a precautionary approach, wherein «the mitigation agenda should proceed on the premise that [CDR] will not work at scale» (Anderson and Peters 2016). This is because embarking today on an emissions pathway that assumes successful large-scale deployment of CO_2 removal in the future leads to a breach of the carbon budget if this deployment fails to materialize: Reliance on CDR allows modelled scenarios to follow less stringent emissions pathways in the near term since later removal essentially increases the available net CO_2 emissions budget. In a recent study, we show that restricting CDR to zero requires 2030 benchmark emissions of CO_2 to be at least one third lower than in a scenario with a full complement of CDR options (22.2 vs 32.2 $GtCO_2$) (Holz, Siegel, et al. 2018). This indicates the importance of increasing mitigation ambition in the very near term if a precautionary approach to CDR is to be followed.

[...]

BECCS' large demand for land has been pegged at about 30–160 million hectares (Mha) per $GtCO_2$, depending on the type of bioenergy feedstock used (Smith et al. 2015). This means that land in the order of 600–3,200 Mha would be required to achieve the 20 $GtCO_2$ magnitude at the upper end of the range of annual sequestration found in the models. In contrast, current global cropland is approximately 1,500 Mha (Dooley et al. 2018), suggesting that massive-scale BECCS deployment would be in strong land-use competition with land currently used for food production, thus undermining efforts to increase food security and end hunger, or with land that is currently forest or other natural land, thus undermining protection of biodiversity and efforts to stop deforestation, itself a major contributor to climate change. Further concerns relate to the amount of water, fertilizer and energy that would be required to implement BECCS at large scales: Researchers at the Potsdam Institute for Climate Impact Research have recently investigated whether large-scale BECSS deployment can be accomplished while taking a precautionary approach to important «planetary boundaries» (freshwater use, forest loss, biodiversity, and biogeochemical flows, e.g. fertilizer) and found that only about 0.2 GtCO_2 per year can be achieved this way, several orders of magnitude below what is typically assumed in models (Heck et al. 2018). Exceeding this amount would push at least one of these planetary boundaries (further) into the uncertainty or high-risk range.

Other proposed CDR technologies share similar concerns. For example, DAC requires large amounts of energy to enable the chemical reactions that remove the CO_2 from the atmosphere plus energy to liquify, transport and store the CO_2 once captured. EW is an approach where rock, for example olivine, is mined, ground and then spread out over large areas to facilitate its weathering which binds CO_2. These steps require large amount of energy, similar in scale to the energy requirement of DAC. The energy required for these approaches is estimated to be as much as 12.5 GJ per ton of CO_2 (Smith et al. 2015). Considering that generating 12.5 GJ of electricity with coal would emit about 3.5 tons of CO_2 (or 2.9 or 1.6 tons of CO_2 with oil and natural gas, respectively)[10] highlights that these approaches are not a plausible alternative to fossil fuel phase-out. Furthermore, these CDR technologies are very costly with estimates for DAC and EW exceeding US$ 500 per ton of net negative CO_2 (Smith et al. 2015).

Models also often include sequestration of CO_2 from forests. It is important to distinguish this sequestration from the CDR approaches outlined above, even though models, or literature discussing model results, often do not make this distinction. Broadly speaking, forest-based sequestration can occur through afforestation or through natural sequestration by forests. Because it involves establishment of tree plantations on land that would not otherwise carry forest, afforestation shares many of the issues of the CO_2 removal approaches discussed above: to sequester large amounts to CO_2, it requires large amounts of land (thus competing with food and other land uses), nutrients, and water.

In contrast, where deforestation and forest degradation are halted, forest can be restored or re-established. In that context, natural sequestration of CO_2 by these forest would occur, potentially in the magnitude of several hundred GtCO_2 over the course of the 21st century (Dooley and Kartha 2018). However, since the carbon thus stored in the biosphere is at risk of being re-emitted to the atmosphere, for example, if pests, forest fires, or human activity were to destroy these forests, it remains risky and thus a violation of the precautionary principle to rely on these processes to occur when articulating near-term mitigation ambition. This is especially true where scenarios delay the rapid phase-out of fossil fuel use, given that existing fossil fuel deposits represent a stable way of storing carbon unlike potentially volatile storage in the biosphere.

[...]

"The majority of 1.5 ° C scenarios in the literature are so-called overshoot scenarios: they result in warming of more than 1.5 ° C during some years of the 21st century, to return to the 1.5 ° C level by 2100 the latest. Temperature overshoot carries substantial potential risks and uncertainties, for example, with regard to the irreversible crossing of tipping points, or the permanence of warming impacts: «Impacts that could be wholly or partially irreversible include species extinction, coral reef death, [permafrost melt], and loss of sea or land ice, some of which themselves lead to positive feedbacks or tipping points that current carbon cycle models do not currently take into account» (Dooley and Kartha 2018). Due to their assumed ability to remove CO2 from the atmosphere, and thus bring temperatures back down, scenarios using large amounts of CDR often display longer overshoot periods with higher peak warming than scenarios with less (or no) CDR."

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10 Using median values of the survey of life cycle analyses of emissions of different fuel types conducted by the IPCC: 1001 gCO_2/kWh for coal, 840 gCO_2/kWh for oil, and 469 gCO_2/kWh for natural gas (IPCC 2011).

Annex 2. The LED scenario

Source: CSO Equity Review (2018) *After Paris: Inequality, Fair Shares, and the Climate Emergency*, CSO Equity Review Coalition, Manila, London, Cape Town, Washington, et al., http://civilsocietyreview.org/report2018

"In order to place a fair-share discussion of national mitigation pledges firmly in the context of the climate challenge, it's necessary to have a proper 1.5°C scenario. Such a scenario must not only specify a path that keeps warming below 1.5°C, it must do so in a manner that is fair with respect to energy access, consumption, and other critical aspects of human well-being. To reflect such a future, we've chosen the Low Energy Demand scenario as our illustrative scenario. The LED scenario is the source of one of the four featured pathways (P1) in the IPCC's 1.5°C report. This scenario was developed at the International Institute for Applied Systems Analysis and is explicitly designed to be equitable in just these ways – by taking the universal attainment of a 'decent living standard' as one of its design criteria – but also to avoid the problem, endemic in mainstream mitigation scenario modelling, of excessive reliance on negative emissions technologies.

The Low Energy Demand (LED) scenario incorporates many current major trends in energy demand, trends that are already observable and expected to intensify, including urbanization, digitalization, the decentralization of the energy system, the shift from ownership-based to use-based consumption of services, and the emergence of a circular economy to limit material use and waste. These trends, together with other substantial increases in energy efficiency across all sectors, lead to very low energy demand projections (e.g. 42% below 2020 levels in 2050), despite population growth and a global increase in end-use energy services, including temperature-controlled housing, adequate and nutritious diets, and accessible transportation services. The point here is not to endorse all details of the LED scenario but rather to note that, in an energy system that's meant to satisfy this comparatively low overall future energy demand, it becomes much less daunting to rapidly retire fossil-fuel-based generation and transition to renewables.

Because of these features, the LED scenario can satisfy humanity's energy needs without, like many ostensible 1.5°C scenarios, assuming a heavy future reliance on negative emissions, for example through large-scale bioenergy with carbon capture and storage (BECCS), the feasibility and sustainability of which have not been proven at scale. It's ability to do so derives, in part, from the fact that the global forest sink can be enhanced significantly when there is reduced competition for land from bioenergy crops.

Compared to current (2016) global greenhouse gas emissions of about 50 gigatonnes of carbon dioxide equivalent ($GtCO_2eq$), the LED pathway enables very stringent reductions, eliminating half of current emissions by 2030 (these reach 25 $GtCO_2eq$), only about 10 $GtCO_2eq$ in 2050, and a mere 1.5 $GtCO_2eq$, primarily for agriculture, in 2100. It's important to note, however, that even more could be done. The LED pathway assumes that the economies of even the developed countries continue to expand, with incomes nearly tripling by the century's end. Clearly, even deeper reductions – and a less threatened climate – could be achieved if steadily accelerating growth was not assumed."

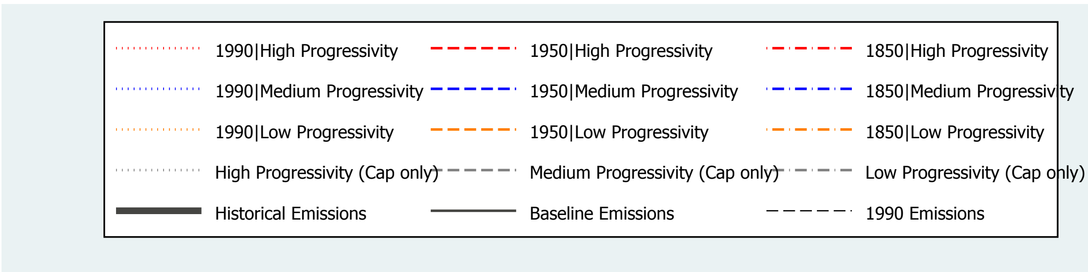
Annex 3: Notes on the Equity analysis used here

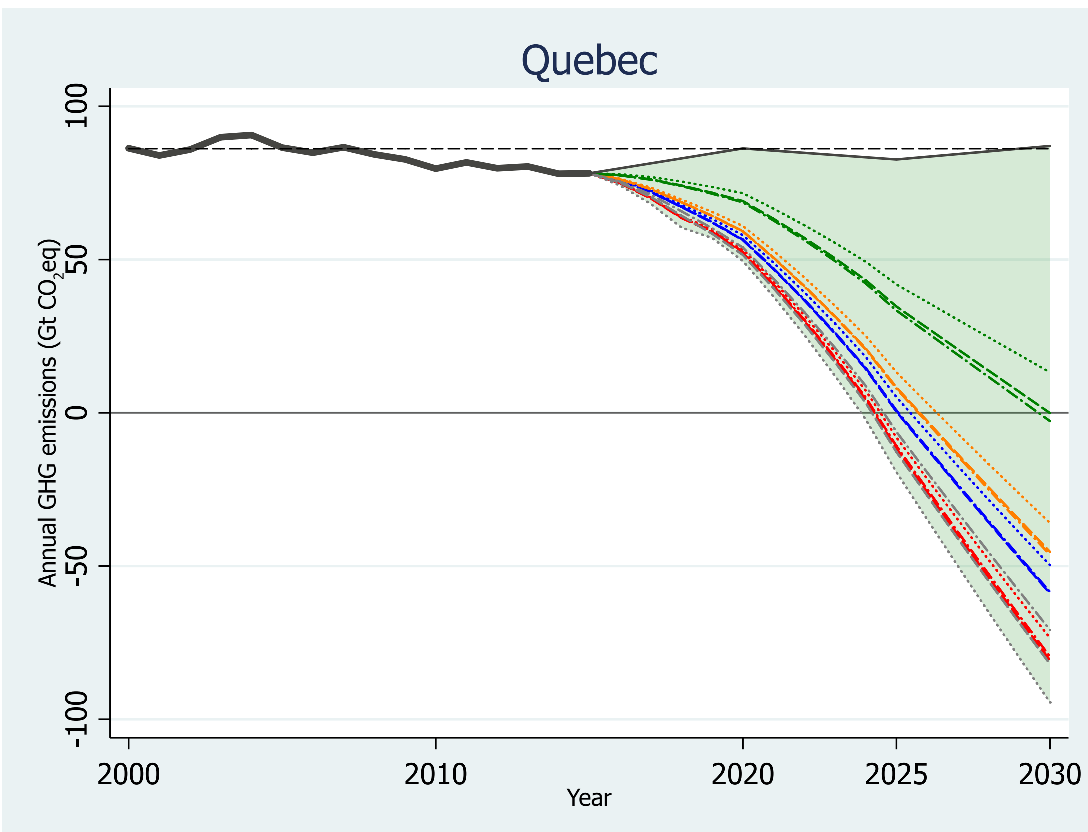
Capacity – a nation's financial ability to contribute to solving the climate problem – can be captured by a quantitative benchmark defined in a more or less progressive way, making the definition of national capacity dependent on national income distribution. This means a country's capacity is calculated in a manner that can explicitly account for the income of the wealthy more strongly than that of the poor, and can exclude the incomes of the poorest altogether.

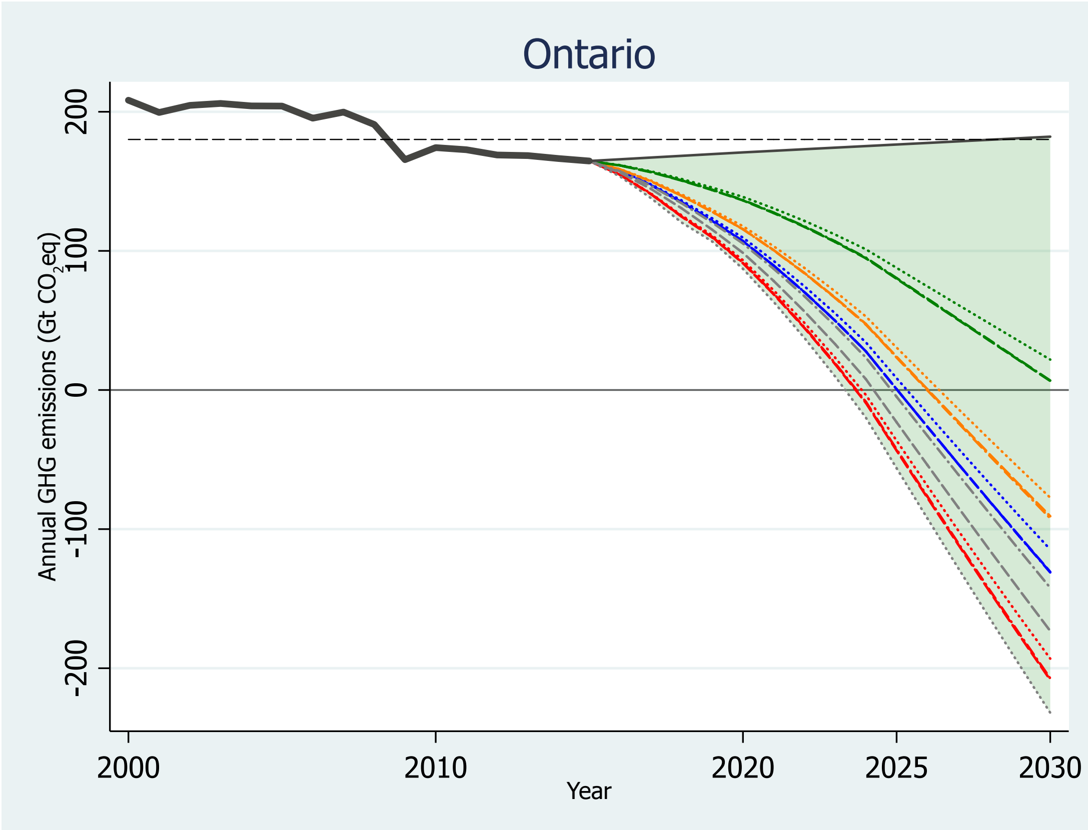
Similarly, ***Responsibility*** – a nation's contribution to the planetary GHG burden – can be based on cumulative GHG emissions since a range of historical start years, and can consider the emissions arising from luxury consumption more strongly than emissions from the fulfilment of basic needs, and can altogether exclude the survival emissions of the poorest. Of course, the 'right' level of progressivity, like the 'right' start year, are matters for deliberation and debate.[11]

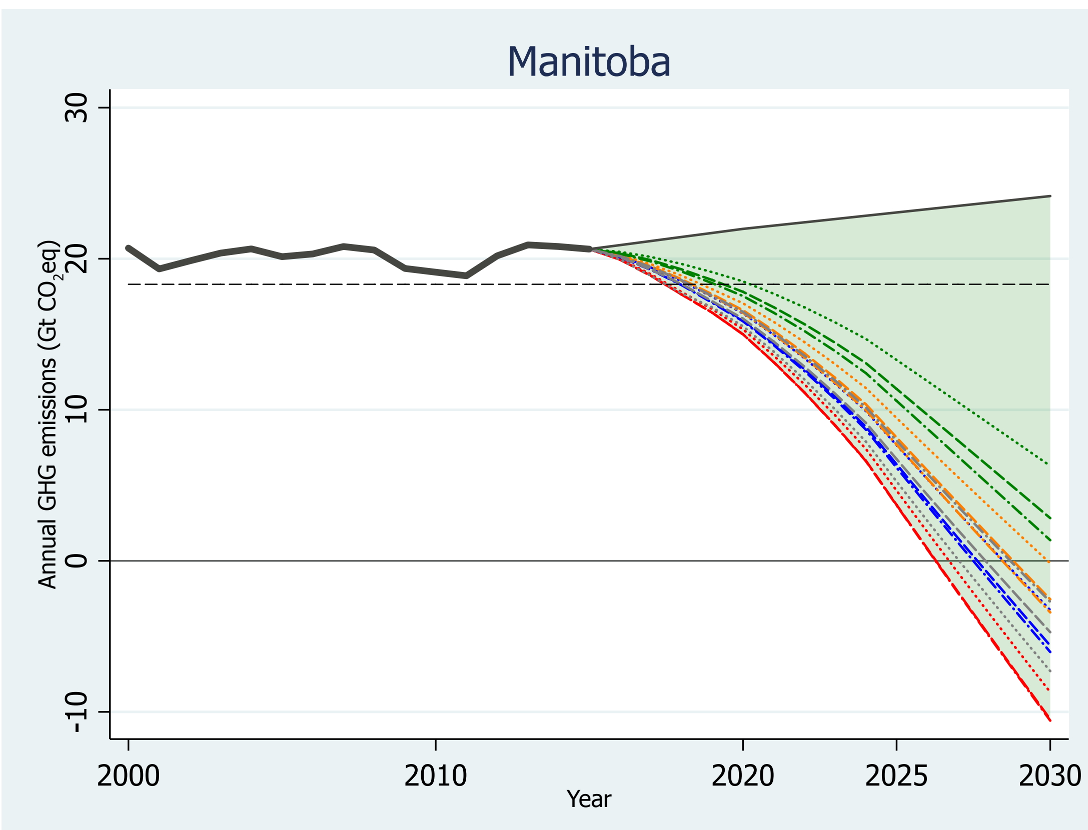
11 For more details, including how progressivity is calculated and a description of the standard data sets upon which our calculations are based, see About the Climate Equity Reference Project Effort-sharing Approach: https://climateequityreference.org/about-the-climate-equity-reference-project-effort-sharing-approach/. For an interactive experience and a finer set of controls, see the Climate Equity Reference Calculator (https://calculator.climateequityreference.org). The CSER methodology is described in a peer-reviewed methodology article, which provides further details (Holz, Kartha, et al. 2018a).

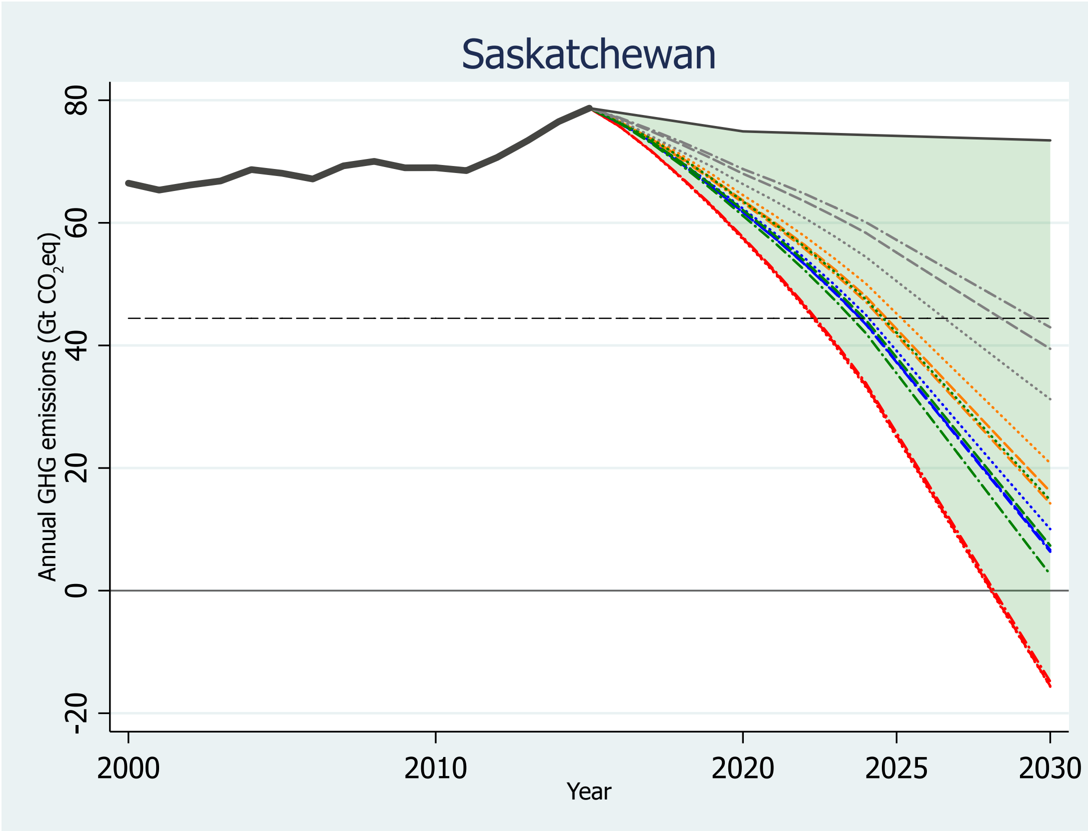
Annex 4: Effort Sharing Calculations for Canadian provinces under a variety of parameterizations

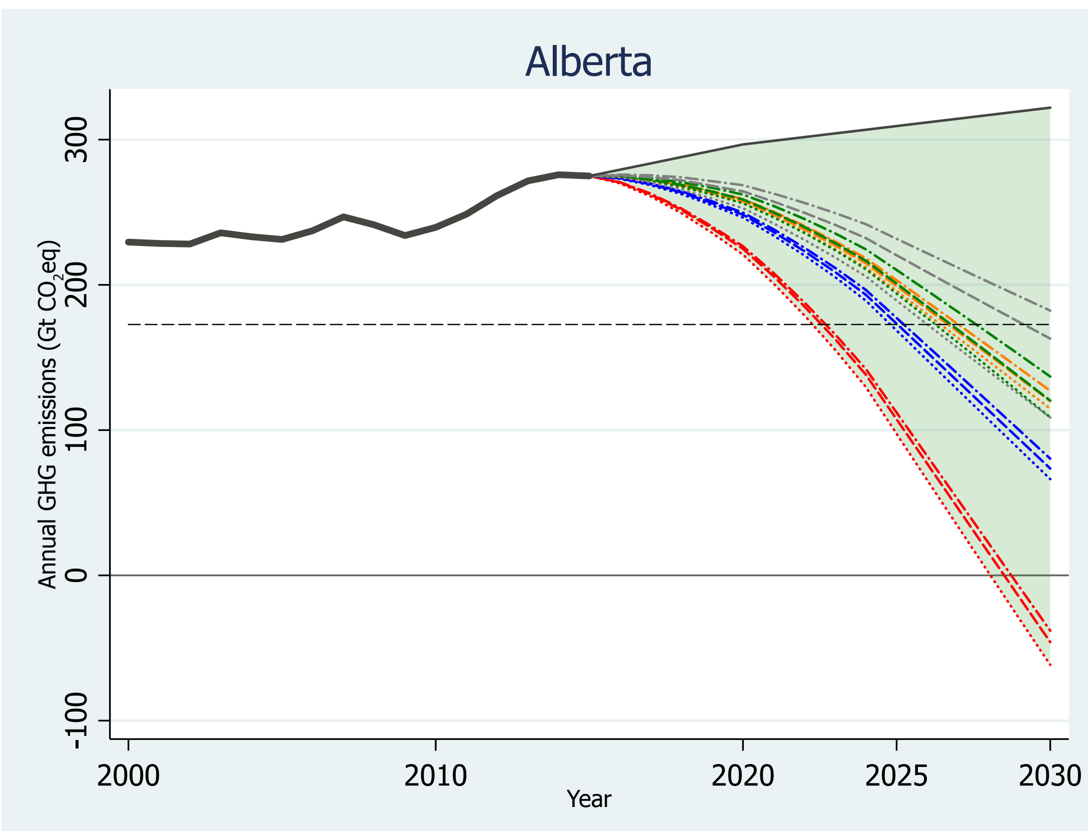


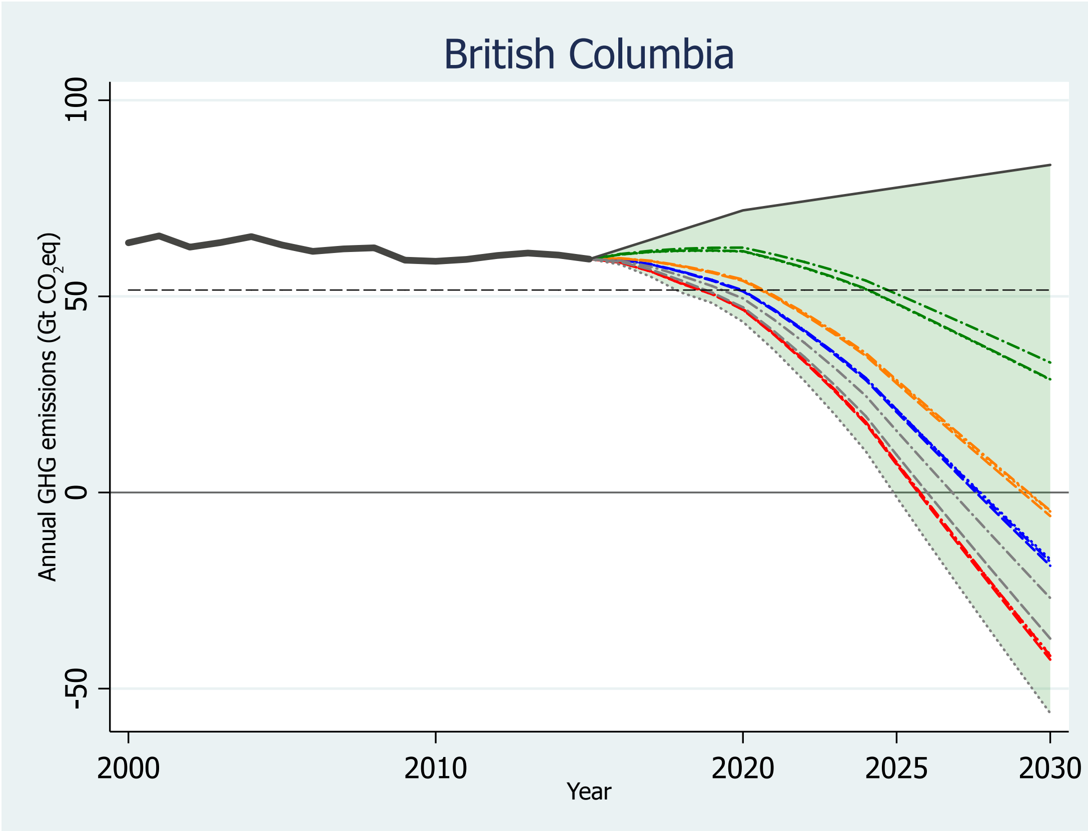


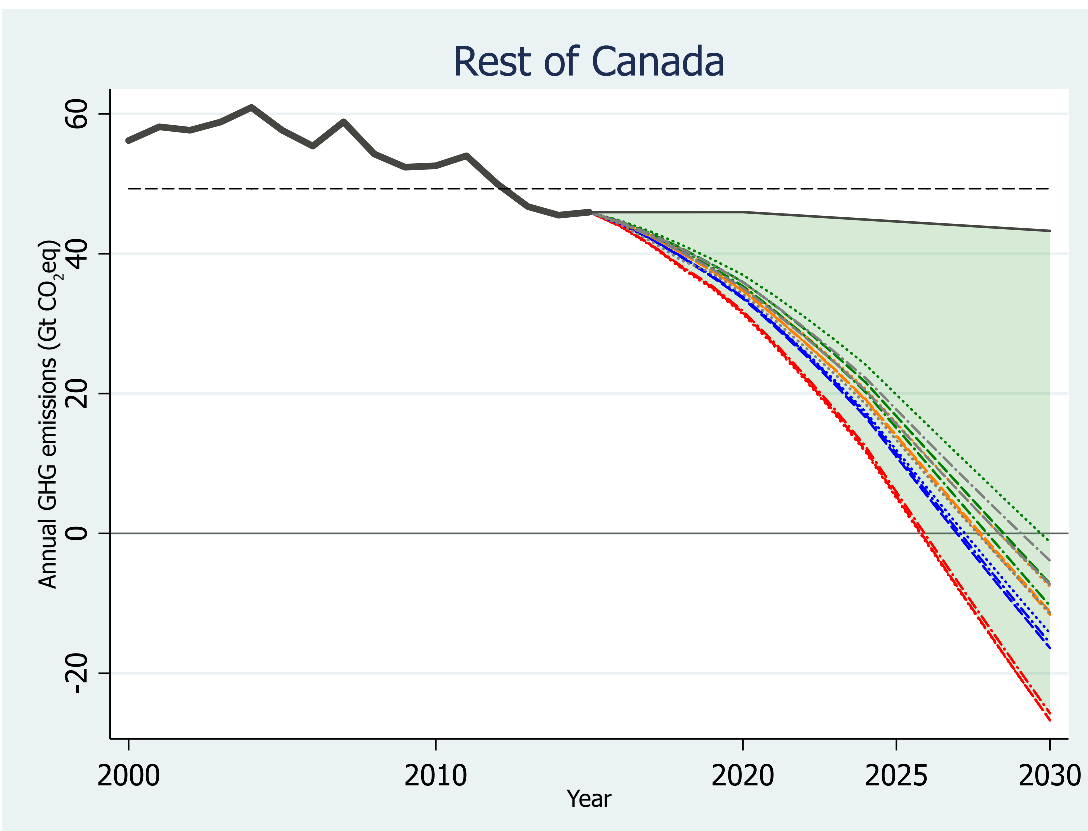

Ontario
Annual GHG emissions (Gt CO_2eq)
200
100
0
-100
-200
2000
2010
2020
2025
2030
Year


Manitoba
Annual GHG emissions (Gt CO_2eq)
30
20
10
0
-10
2000
2010
2020
2025
2030
Year


Saskatchewan
Annual GHG emissions (Gt CO_2eq)
80
60
40
20
0
-20
2000
2010
2020
2025
2030
Year


Alberta
Annual GHG emissions (Gt CO_2eq)
300
200
100
0
-100
2000
2010
2020
2025
2030
Year


British Columbia
Annual GHG emissions (Gt CO_2eq)
100
50
0
-50
2000
2010
2020
2025
2030
Year


Rest of Canada
Annual GHG emissions (Gt CO_2eq)
60
40
20
0
-20
2000
2010
2020
2025
2030
Year

Ontario

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	1990 levels %
Benchmarks considering Capacity and Responsibility					
Low	1850	0.76%	274.4	272.3	151.2%
	1950	0.75%	272.9	270.9	150.4%
	1990	0.72%	259.5	257.5	143.0%
Medium	1850	0.86%	313.3	311.3	172.8%
	1950	0.86%	312.9	310.9	172.6%
	1990	0.82%	296.7	294.7	163.6%
High	1850	1.07%	389.4	387.4	215.1%
	1950	1.08%	390.5	388.5	215.7%
	1990	1.03%	375.2	373.2	207.2%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.89%	324.3	322.3	178.9%
Medium	not considered	0.98%	355.4	353.3	196.2%
High	not considered	1.14%	414.2	412.2	228.8%

Manitoba

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	1990 levels %
Benchmarks considering Capacity and Responsibility					
Low	1850	0.08%	27.6	21.7	118.6%
	1950	0.07%	26.7	20.9	113.9%
	1990	0.07%	24.3	18.5	100.9%
Medium	1850	0.08%	30.2	24.3	133.0%
	1950	0.08%	29.8	23.9	130.7%
	1990	0.08%	27.4	21.6	117.8%
High	1850	0.10%	34.7	28.9	157.8%
	1950	0.10%	34.6	28.8	157.3%
	1990	0.09%	32.8	27.0	147.5%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.07%	26.9	21.0	114.8%
Medium	not considered	0.08%	28.9	23.0	125.8%
High	not considered	0.09%	31.4	25.6	139.8%

Saskatchewan

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	%
Benchmarks considering Capacity and Responsibility					
Low	1850	0.16%	59.2	30.2	68.0%
	1950	0.16%	57.3	28.3	63.6%
	1990	0.15%	52.7	23.6	53.2%
Medium	1850	0.19%	67.1	38.1	85.7%
	1950	0.18%	66.8	37.8	85.1%
	1990	0.17%	63.4	34.4	77.4%
High	1850	0.24%	88.3	59.3	133.4%
	1950	0.25%	89.0	60.0	135.0%
	1990	0.25%	89.1	60.1	135.3%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.08%	30.5	1.5	3.3%
Medium	not considered	0.09%	34.0	5.0	11.2%
High	not considered	0.12%	42.2	13.2	29.7%

Alberta

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	%
Benchmarks considering Capacity and Responsibility					
Low	1850	0.54%	194.9	45.6	26.4%
	1950	0.56%	202.0	52.7	30.5%
	1990	0.57%	207.3	58.0	33.6%
Medium	1850	0.67%	241.6	92.4	53.5%
	1950	0.69%	248.4	99.2	57.4%
	1990	0.71%	255.7	106.4	61.6%
High	1850	0.99%	360.1	210.8	122.0%
	1950	1.01%	367.9	218.6	126.6%
	1990	1.06%	383.6	234.3	135.6%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.39%	139.7	-9.5	-5.5%
Medium	not considered	0.44%	159.0	9.7	5.6%
High	not considered	0.59%	213.2	64.0	37.0%

British Columbia

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	1990 levels %
Benchmarks considering Capacity and Responsibility					
Low	1850	0.24%	88.1	56.2	108.9%
	1950	0.25%	89.5	57.6	111.6%
	1990	0.24%	88.4	56.5	109.4%
Medium	1850	0.28%	101.2	69.3	134.3%
	1950	0.28%	102.2	70.3	136.2%
	1990	0.28%	100.6	68.7	133.0%
High	1850	0.35%	125.2	93.3	180.7%
	1950	0.35%	126.1	94.2	182.6%
	1990	0.34%	124.9	93.0	180.2%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.30%	110.4	78.5	152.1%
Medium	not considered	0.33%	120.8	88.9	172.2%
High	not considered	0.39%	139.8	107.9	209.0%

Rest of Canada

Progressivity Approach	Historical Responsibility Start Date	Share of Global Effort %	Reductions in 2030 below Baseline Mt CO_2eq	Reductions in 2030 below 1990 levels Mt CO_2eq	1990 levels %
Benchmarks considering Capacity and Responsibility					
Low	1850	0.15%	54.9	60.9	123.6%
	1950	0.15%	54.5	60.5	122.7%
	1990	0.14%	50.9	56.9	115.5%
Medium	1850	0.16%	58.9	64.9	131.8%
	1950	0.16%	59.7	65.7	133.3%
	1990	0.16%	57.5	63.6	129.0%
High	1850	0.19%	69.0	75.0	152.2%
	1950	0.19%	70.0	76.0	154.3%
	1990	0.19%	70.0	76.0	154.2%
Benchmarks considering Capacity only (disregarding Responsibility)					
Low	not considered	0.13%	47.2	53.2	107.9%
Medium	not considered	0.14%	50.6	56.6	114.8%
High	not considered	0.15%	54.6	60.6	123.0%

Annex 5: Notes on Sourcing and Estimating Province Level Data

- Dataset available from author upon request
- Primary Data source for all countries is the composite Climate Equity Reference Calculator Database ("CERP Core DB" (Holz, Kartha, et al. 2018b) at https://doi.org/10.7910/DVN/O3H22Z), which in turn is based on the most authoritative and complete data sources available (see database description at https://doi.org/10.7910/DVN/O3H22Z/FBXUWU for details)
- For Canadian provincial analysis, the data for Canada in the CERP Core DB was replaced with provincial-level data using high quality primary data, primarily from StatsCan and ECCC. For consistency, in some cases, the Canadian absolute totals in the CERP Core DB were retained but allocated to provinces according to the proportional shares in the Canadian primary data sources. See below for details. Projections, interpolations and extrapolations as described below.

- <u>Population</u>
    - Future: 2020-2030 based on values from StatsCan table 17-10-0057-01, from the "Projection scenario LG: low-growth" (Statistics Canada 2020a). This is the StatsCan projection scenario for which the Canadian totals are most consistent with the Canadian figures of the medium growth scenario from the UN population projections, which are used in the CERP Core DB.
      2020-2030 uses the CERP Core DB figures (which in turn are from UN Population projections, medium growth scenario) and applies the shares of provinces/territories of the Canadian total from StatsCan table 17-10-0057-01
    - History: 1971-2019, uses StatsCan table 17-10-0005-01 (Statistics Canada 2020b); for consistency, applies province/territory shares of total population from StatsCan table to CERP Core DB figures
    - Deep History: 1850-1970: uses StatsCan Table A2-14 (Population from Censuses 1851-1971) (Basavarajappa and Ram 2008; Statistics Canada 2008a) with: linear extrapolation between census years and back from 1851 to 1850; extrapolation for provinces/territories that joined Canada later, based on constant ratio to Rest of Canada population in the first year that they are included in the census. From deep history data, used province/territory shares for each year and applied it to deep history Canada population figures from CERP Core DB

- <u>GDP</u>
    - History: For consistency, using GDP figures for Canadian totals from CERP Core DB from 1850 to 2015
    - Recent history and future: 2016-2030 Canadian total percentage change based on Conference Board figures; provincial/territorial breakdown based on provincial/territorial breakdown of Canadian total in Conference Board figures (Conference Board of Canada 2019)
    - History: 1981-2015: uses StatsCan table 36-10-0222 (Statistics Canada 2020c). For consistency, applies province/territory shares of total GDP from StatsCan table 36-10-0222 to CERP Core DB figures
    - Deep History 1850-1980:
        - Was unable to find provincial breakdown of GDP before 1981
        - However, we do have GDP time series for the whole of Canada going back to 1850 in the CERP Core DB, thus need an appropriate algorithm to split this onto provinces:
            - from 1926-1976, was able to find "personal income" by provinces from StatsCan (Crozier 2008; Statistics Canada 2008b). These figures were used as a proxy for the split of GDP between provinces and each province's fraction of the total Canadian personal income for each year was applied to the Canadian

GDP from the CERP Core DB. (including linear extrapolation from 1976 to 1980; and linear extrapolation back to 1926 for provinces that joined Canada after 1926, using constant GDP share of provinces of the first data year after joining)

- for 1850-1925: used population figures from StatsCan table A2-14 (Statistics Canada 2008a) and assumed relative difference between provincial and Canadian average per capita personal incomes to be constant at average 1926-1930 levels across the 1850-1925 period, using the formula

$$y_{i,t} = p_{i,t} \cdot \frac{Y_t}{P_t} \cdot \frac{\sum_{j=1926}^{1930} \frac{y_{i,j}/p_{i,j}}{Y_j/P_j}}{5}$$

where $y_{i,t}$ is the provincial income for province i in year t, Y the total Canadian income in year t, and where $p_{i,t}$ is the provincial population for province i in year t, P the total Canadian population in year t. The term $\frac{y_{i,j}/p_{i,j}}{Y_j/P_j}$ captures the ratio of how much larger or smaller the average per capita income of province i ($y_{i,j}/p_{i,j}$) is relative to the average Canadian per capita income (Y_j/P_j), in year j. For extrapolating income backwards from 1926 to 1850, we use the 5 year average of that ratio over the 1926-1930 period and keep it constant, when calculating provincial incomes for any given earlier year t by multiplying the ratio with the Canadian average income for that year (Y_t/P_t) and the provincial population ($p_{i,t}$)

- <u>Emissions</u>
  - No LULUCF emissions/removals considered
  - No Emissions embodies in trade ("consumption emissions") implemented
  - History 1990-2015: directly taken from NIR, with provincial breakdown as provided in ECCC data mart (ECCC 2019a)
  - Projections 2016-2030: with measures scenario from BR2 2015 (Canada 2016a, 2016b), also highlighted as a sort of baseline scenario in 2019 ECCC projections paper (ECCC 2019b), situating it as "the last projection before PCF" (and PA), and contrasting it with 2019 projection from BR4 (Canada 2019). Linear Extrapolation between 2015 and 2020 and 2020 and 2030, respectively. Quebec projection overridden with values from Dunsky (Dunsky et al. 2019)
    - Table 6(a) of BR2 CRF (Canada 2016b), or table 5-3 in the text of BR2 (Canada 2016a), provides gas breakdown for Canada for 2020 and 2030, totals slightly different than numbers from 2019 projections paper
    - 2019 projection paper provides totals for Canada on annual basis
    - Table A24 in BR2 text has provincial breakdown (in MtCO2eq)
    - Charts in Dunsky report provide 5-year intervals for Quebec reference scenario projection and breakdown of sectors (Ag and Waste serve as nonCO2 proxy)
    - → table 5-3 of BR2 has essentially unchanged split of CO2 vs non-CO2 in 2020 and 2030 (79% CO2), Chart in Dunsky report has similar figure (82%) for QC → assume CO2 vs non CO2 split remains constant for each province or territory from 2020 to 2030, except using QC figures from Dunsky. Converge to constant 2020 value from actual 2015 values
  - Deep History: 1850-1989
    - For CO_2, using the CO_2 intensity of GDP (kg CO_2/$) and for non-$CO_2$ using per capita emissions (kg CO_2eq/cap).

      Specifically, for CO_2 emissions, we use the formula

$$e_{i,t} = y_{i,t} \cdot \frac{E_t}{Y_t} \cdot \frac{\sum_{j=1990}^{1995} \frac{e_{i,j}/y_{i,j}}{E_j/Y_j}}{5}$$

where $e_{i,t}$ are the provincial CO_2 emissions for province i in year t, E the total Canadian CO_2 emissions in year t, and where $y_{i,t}$ is the provincial GDP for province i in year t, Y the total Canadian GDP in year t. The term $\frac{e_{i,j}/y_{i,j}}{E_j/Y_j}$ captures the ratio of how much the average CO_2 intensity of GDP for province i ($e_{i,j}/y_{i,j}$) is larger or smaller relative to the average Canadian CO_2 intensity of GDP (E_j/Y_j), in year j. For extrapolating CO_2 emissions backwards from 1989 to 1850, we use the 5 year average of that ratio over the 1990-1995 period[12] and keep it constant, when estimating provincial CO_2 emissions for any given earlier year t by multiplying that ratio with the Canadian average CO_2 intensity of GDP for that year (E_t/Y_t) and the provincial GDP ($y_{i,t}$). Provincial emissions are proportionally calibrated for each year so that the total across provinces matches the total for Canada from the CERP Core DB for that year.

For non-CO_2 greenhouse gas emissions, we use the formula

$$e_{i,t} = p_{i,t} \cdot \frac{E_t}{P_t} \cdot \frac{\sum_{j=1990}^{1995} \frac{e_{i,j}/p_{i,j}}{E_j/P_j}}{5}$$

where $e_{i,t}$ are the provincial non-CO_2 emissions for province i in year t, E the total Canadian non-CO_2 emissions in year t, and where $p_{i,t}$ is the provincial population for province i in year t, P the total Canadian population in year t. The term $\frac{e_{i,j}/p_{i,j}}{E_j/P_j}$ captures the ratio of how much larger or smaller the average per capita non-CO_2 emissions of province i ($e_{i,j}/p_{i,j}$) are relative to the average Canadian per capita non-CO_2 emissions (E_j/P_j), in year j. For extrapolating income backwards from 1989 to 1850, we use the 5 year average of that ratio over the 1990-1995 period and keep it constant, when estimating provincial non-CO_2 emissions for any given earlier year t by multiplying the ratio with the Canadian average per capita non-CO_2 emissions for that year (E_t/P_t) and the provincial population ($p_{i,t}$). Provincial emissions are then proportionally calibrated for each year so that the total across provinces matches the total for Canada from the CERP Core DB for that year.

- Gini Coefficients
    - 1976-2018 for provinces using Gini coefficients s for "adjusted market income" from StatsCan Table 11-10-0134-01 (Statistics Canada 2020d) (adjusted market income is the time series where the values for Canada match best the CERP Core DB)

12 Admittedly, this is a somewhat arbitrary time span. Essentially, we are assuming the *structure* of the difference of carbon intensities of the provincial economies to be constant over time all the way back to 1850. We know this is not true, but in order to get the estimate closest to real values, we want to pick a reference period that's as far back as possible, before the most recent structural changes occurred, and we don't want to pick a single year, since carbon emissions can be quite different from year to year (think, a single cold winter requiring unusual amounts of heating), so a five year average hopefully smooths that out a bit. Either way, the strongest predictor of emissions is GDP, and we do have a decent time series for GDP or its proxies. The alternative to the approach used here (assuming relative carbon intensity to be constant for every province across time but different between provinces) would be assuming the carbon intensity to be constant across provinces in each year, but different across time.

- For pre 1976 and post 2019 for provinces, using Canada values from CERP Core DB, constant across provinces
- For territories, using Canada values from CERP Core DB throughout

- PPP2MER conversion rate
    - Using Canada values from CERP Core DB throughout

Dataset limitations

Provincial breakdown limitations in primary data

- GDP only from 1981, personal income (as proxy for GDP) from 1926
- Population only from 1971
- Emissions only from 1990
- Gini Coefficients only from 1976

(though data set filled in with estimates as per above from 1850-current)