FRASER RESEARCH BULLETIN

FRASER INSTITUTE

2022

CO_2 is CO_2 is CO_2—the Implications for Emissions Caps

by William Watson

MAIN CONCLUSIONS

- CO_2 is CO_2 is CO_2: all CO_2 molecules are identical whatever their source.

- To a height of roughly 100 km, the atmosphere is a “homosphere”: its composition is essentially the same throughout.

- Any reduction in the CO_2 put into the atmosphere will therefore have the same effect as any other.

- If we decide to reduce the atmosphere’s CO_2 content, economics suggests we do so in the least costly way.

- As a real-word example demonstrates, a family would reduce its CO_2 use by seeking the least costly ways to lower its CO_2 output per activity, as well as the least costly activities that it could reduce or even eliminate.

- A family that wanted to do this rationally would equalize the marginal cost of CO_2 reduction across all its activities, cutting back more on those that are of least benefit to it and less on those that are of most benefit.

- A country is not just a big family. The least costly ways of reducing CO_2 output are known, not to governments, but only to individuals and firms, who have, as Friedrich Hayek put it, “knowledge of the particular circumstances of time and place".

- If a government imposes a price on CO_2 emissions equal to their marginal social cost, people and firms will go about finding the least costly way to reduce their emissions and no further intervention will be required.

Introduction

Should our approach to carbon dioxide (CO_2) emissions depend on which industry, sector, region, or activity the emissions come from? Even uniform, economy-wide policies such as carbon taxes or cap-and-trade emissions markets will have differential *impacts* across industries, regions, and so on. But, should the policies themselves differ from source to source? To take an example from the headlines, should either the federal or a provincial government cap emissions from Canada's oil and gas sector, whether at current levels, as Prime Minister Justin Trudeau promised at COP26 in Glasgow in the fall of 2021 (Rabson, 2021), or at an arbitrary level such as the 100-billion tonne CO_2-equivalent cap that has been Alberta's legislated target for the oil sands since 2016 (Alberta, 2016)?

This analysis argues that they should not, for two main reasons. First, the source of CO_2, which causes a buildup of greenhouse (GHG) gases in the atmosphere, is irrelevant from an environmental perspective: the effect of each CO_2 molecule is the same regardless of its origin. And, second, according to basic economic theory, any reduction in emissions should be done at the least possible cost, a principle demonstrated here by looking at emissions reduction in a single household (my own). In general, as the example will show, arbitrary caps or targets on individual sources will reduce emissions at a greater cost than necessary.

Two facts about CO_2 and the atmosphere

When Gertrude Stein wrote "Rose is a rose is a rose is a rose" in her 1913 poem, "Sacred Emily", the first "Rose" was (as here) capitalized and referred to an actual person named Rose. In subsequent years, the "three-rose" version of the quote, with "Rose is" omitted, took on deeper meaning, whether as an illustration of the Identity Law (that is, $A \equiv A$) or as a contribution to continuing debate about meaning, reality, and existence. As a statement about roses, however, it is in fact incorrect. As FTD tells us there are more than "150 species of rose and thousands of hybrids" (FTD, 2017).

This Bulletin's title (*CO_2 is CO_2 is CO_2*) is not meant to be nearly so deep but merely states that, unlike roses, carbon dioxide comes in only one variety. This means the effect of CO_2 molecules on climate change does not vary based on their source, but only on the existing concentration of CO_2 in the atmosphere, a fact that has important implications for how policy makers reduce emissions of it.

A second relevant scientific fact is that the first 100 kilometres of atmosphere—upward from the surface of the Earth—is a "homosphere", in which gases are more or less perfectly mixed by turbulence as wind and eddies stir them. Above the homosphere, the atmosphere is a "heterosphere" and its composition is not uniform. High up, the processes that effectively stir the air do not operate or are dominated by properties of the gases themselves.

NASA TV offers a 3D rendering of the "complex patterns in which carbon dioxide in the atmosphere increases, decreases and moves around the globe", all based on supercomputer-processing of almost 100,000 observations per day taken by a NASA satellite between September 2014 and September 2015 (NASA, 2016). There is a seasonal pattern to the flows, which, brightly coloured in the simulation, swirl like smoke from a fire. During the northern hemisphere's summer, plants absorb more of the CO_2 generated by major emissions sources so that net emissions are lower and the simulation is less colourful, while during winter the reverse occurs. Because CO_2 enters and leaves the atmosphere all the time, and weather never ceases, neither do the swirls and eddies of the homosphere's mixing of gases. But the homosophere does end up being essentially homogenous.

Its composition is 78% nitrogen, 21% oxygen, 0.95% argon and 0.04% CO_2, with the rest a smattering of neon, helium, methane, krypton, hydrogen, and other substances. Expressed differently, the 0.04% concentration of CO_2 is 400 parts per million. An Olympic-sized swimming pool (50 metres long by 25 metres wide by two metres deep) holds 2.5 million litres. A standard bathtub, by contrast, holds 300 litres. So if you poured three and one-third bathtubs of any liquid into your Olympic-sized pool and stirred vigorously, you would eventually have a solution of 400 parts per million.[1] Even if the liquid were bright red or blue, it probably would not end up making much difference to the final colour of the water in the pool. But, of course small quantities can have big effects: just one eighth of a teaspoon of arsenic will kill a healthy adult (CHE, 2016). The concern surrounding the rise in GHG is that a proportionally large and rapid change even in a small amount such as 400 parts per million may have important effects on the planet's average temperature.

The details of that argument, important as they are, do not matter here. What does matter are the two propositions that all CO_2 is the same and that it is evenly distributed around the world. It follows that, if your goal is to reduce the concentration of CO_2 in the atmosphere, where any particular emission comes from or how or by whom it was generated does not matter.

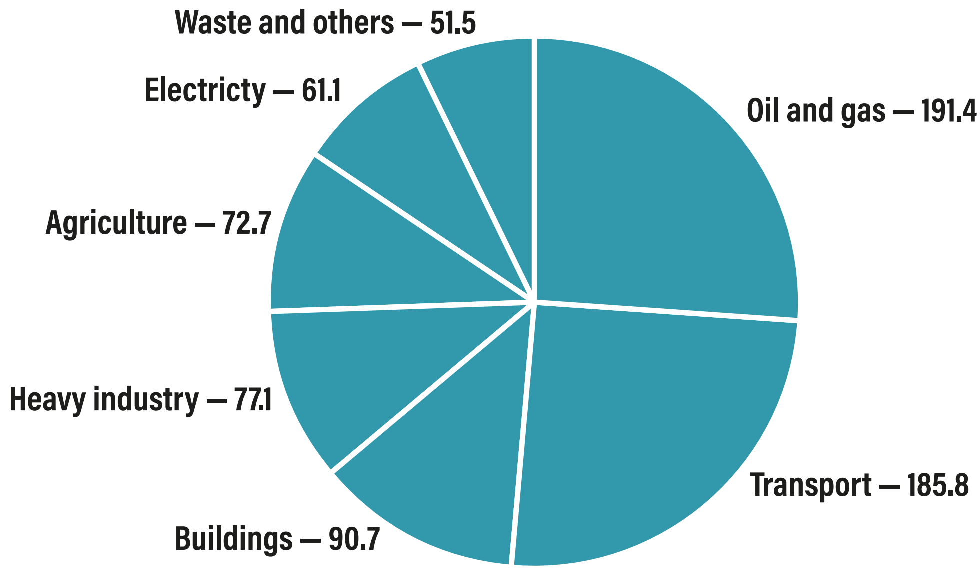
Canadians' production of CO_2

Although where CO_2 comes from may not matter for policy purposes, it may still be of interest to know something about its generation in Canada. In 2021, the federal government published a summary document, *Greenhouse Gas Emissions*, based on the latest data (ECCC, 2021a).[2] Canada's total GHG emissions in 2019 were 730 megatonnes[3] of "carbon dioxide equivalent" (or "Mt CO_2 eq"). That's higher than in 1990 when total emissions were 600 megatonnes but lower than in 2000, when they were 734 megatonnes.[4] Because Canada's population has been growing, GHG emissions per person have actually fallen—to 19.4 tonnes per person in 2019 compared to 21.7 in 1990 (ECCC, 2021a: fig. 2). The peak came in 2003, at 23.4 tonnes per person. One thousand kilograms is almost exactly 13 times the average Canadian's body weight (77 kilograms). In producing 21.7 tonnes of CO_2 equivalent—five Olympic-sized swimming pools worth[5]—the average Canadian is therefore producing roughly 282 times his or her body weight in CO_2. Of course, because natural processes absorb most of the CO_2 we create, that is not our net contribution.

Emissions by sector

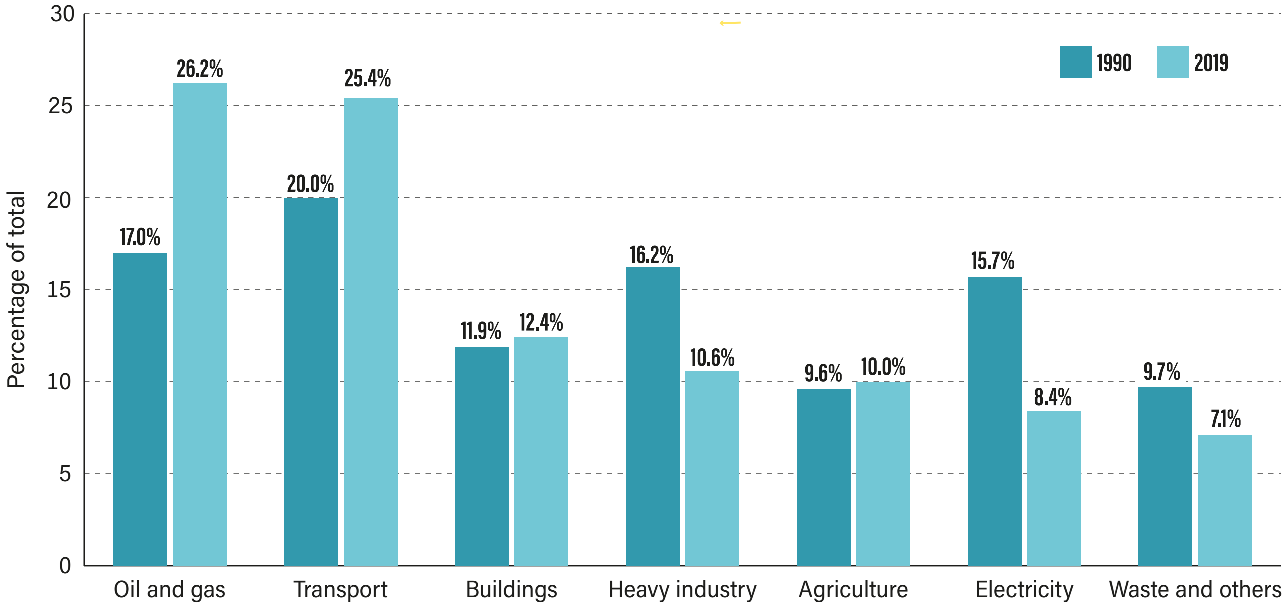
As ***figure 1*** shows, the oil and gas sector produces the most, at 191.4 Mt CO_2 eq. Transport is next (185.8 Mt), then buildings (90.7 Mt), heavy industry (77.1 Mt), agriculture (72.7 Mt), electricity generation (61.1 Mt), and "waste and others" (51.5 Mt). Heavy industry consists of "mining, smelting and refining, pulp and paper, iron and steel, cement, lime and gypsum, and chemicals and fertilizers", while the "others" in "waste and others" include "light manufacturing, construction, forest resources, waste and coal production" (ECCC, 2021a: table A.3, note). In percentages, the 1990 and 2019 shares were as shown in ***figure 2***.

Figure 1: Which economic sectors generate the most CO_2 equivalent (Megatonnes)?



Source: ECCC, 2021a.

Figure 2: Percentage of total emissions by sector, 1990, 2019



Source: ECCC, 2021a.

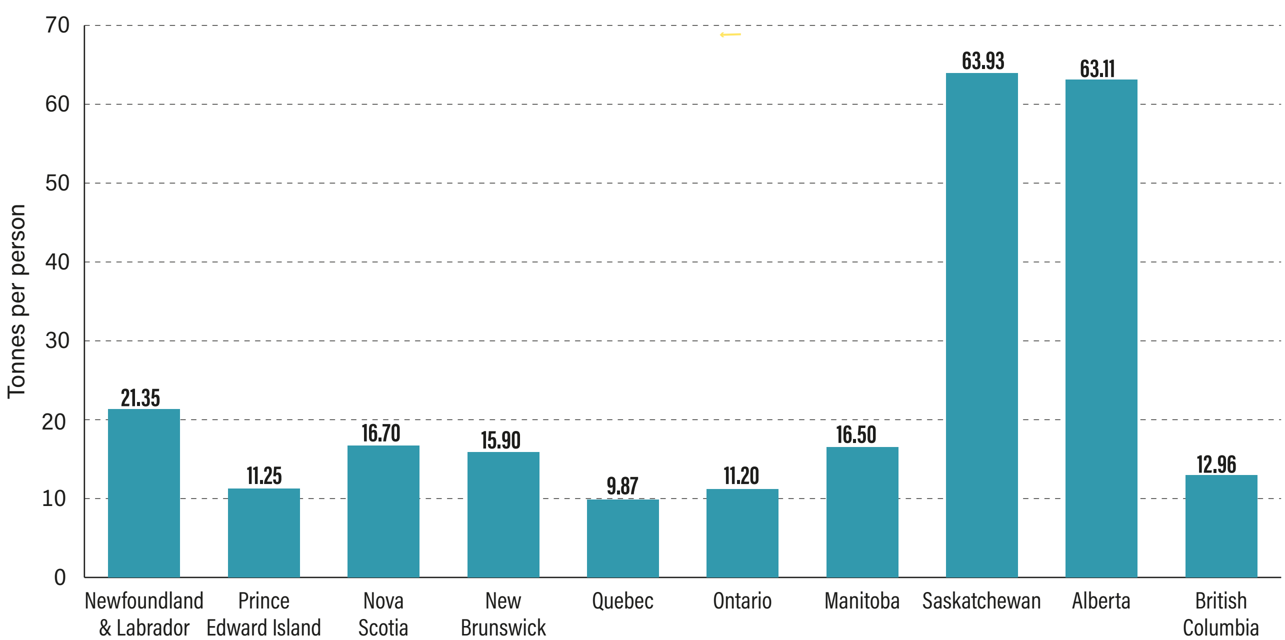
Most of the growth in emissions from the oil and gas industry since 1990 is from oil-sands mining and extraction and *in situ* operations, reflecting that sector's rapid growth over the last three decades. Emissions from the transport sector are mainly from the freight side (including rail, air, and marine). Emissions from passenger cars have actually declined since 1990, though those from light trucks have grown, reflecting their rising share of the passenger fleet. Emissions in electricity generation are mainly from coal-fired plants, although both the share and absolute amount from natural gas have increased (ECCC, 2021a: figures 4, 5, 6).

Emissions by province

Which provinces generate the most emissions? Not surprisingly, since much of the oil and gas industry is situated there, Alberta generates the most with 275.8 megatonnes in 2019, followed by Ontario, the most populous province, with 163.0 megatonnes. At the other end of the spectrum, Prince Edward Island is responsible for only 1.8 megatonnes (ECCC, 2021a: figure 7). On a per-capita basis, however, the distribution is more even, as ***figure 3*** shows. Alberta and Saskatchewan do still stand out but Alberta's per-capita emissions are only 5.6 times Prince Edward Island's, not 153 times, as its total emissions are.

Finally, the federal government also tracks emissions by large emitters, defined as those emitting more than 10,000 tonnes (or 10 kilotons) of CO2 eq, the level at which firms are required by law to report (ECCC, 2021b). In 2019, exactly 1,700 such emitters reported. In total they accounted for 293 megatonnes or 40 per cent of Canada's total emissions for the year. Sixty-one of the 1,700 each accounted for more than one megatonne. On an interactive map (ECCC, 2022), individual sites are indicated by dots. Readers can click on each dot and see its details (i.e., activity, scale, name of operation and so on). As would be expected, the vast majority of dots are in Alberta and southern Ontario, though every province and territory has at least some.

Figure 3: Tonnes of CO_2 equivalent per person, 2019



Sources: ECCC, 2021a; author's calculation.

Reducing the output of CO_2

The subject here is not whether to reduce carbon emissions but rather how best to reduce them if that is the policy goal. Basic economic principles are clear on this problem and also consistent with common sense: start with the easiest reductions first and then, as the sacrifices become greater and greater, make sure every unit of emission reduction involves the same sacrifice across all your different activities. Don't overload on areas where cuts are extremely costly and don't ignore areas where cuts are easy. This is the "equate sacrifices (or benefits) at the margin" rule taught in introductory microeconomics and it applies in any context where choices have to be made across a number of activities, whether it be which goods to consume, how to allocate study time to a set of exams or, in this case, how to reduce the carbon produced across a large, indeed almost infinite, set of activities. The danger of carbon-reduction policies that focus on specific sectors, regions, or activities is that the sacrifices called for from these sectors, regions, or activities will be greater than in other parts of the economy, thus violating the "equate at the margin" rule and involving more cost than is necessary to obtain the desired reduction. Shifting reductions out of these sectors, regions, or activities and into others would therefore produce a net social gain.

Given what may seem the complexity of this rule, however, it might be useful to approach it from a very microeconomic perspective. Here is a practical example that further explains "equating at the margin."

Equating at the margin—a household example

If my wife and I wanted to reduce our household's carbon footprint, how would we go about doing it? To be rational about it, we would start by trying to figure out which activities contribute how much to our family footprint.

The Internet offers many apps to help people calculate their carbon footprints. Natural Resources Canada has one (NRC, 2019), as does the US Environmental Protection Agency (US-EPA, 2016). An app developed in collaboration with the United Nations Climate Change Secretariat estimates the carbon impact of individual consumer purchases (Doconomy AB, 2021). I have used an app from Carbon Footprint (2021) that gets generally good web reviews to generate the data in ***figure 4***, which gives a rough approximation of the emissions our household generates in a year, in this case 2021.

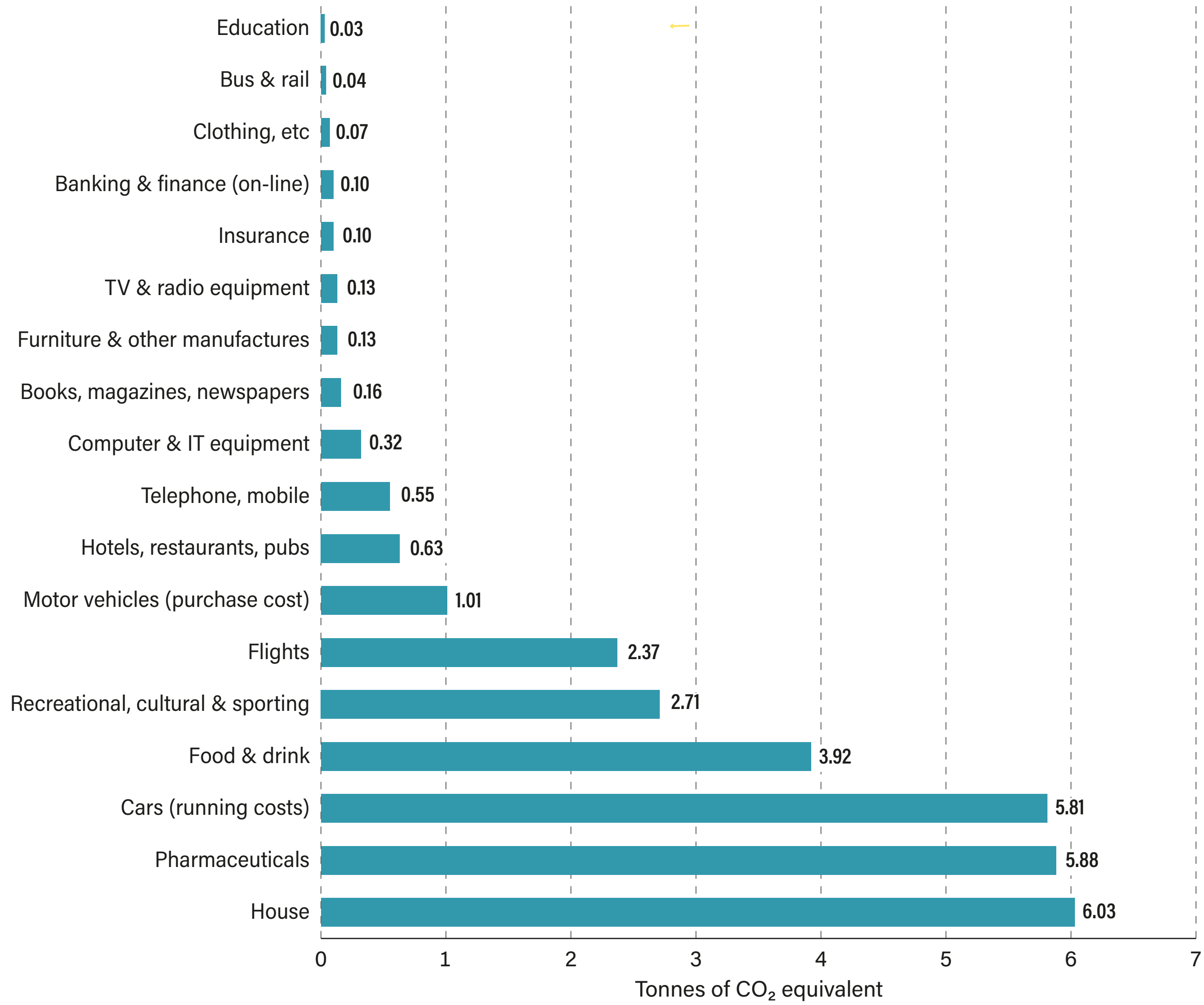
Our biggest carbon impact is from our house. We heat with natural gas and run everything else with electricity, which, because we live in Quebec, is generated with hydro power and therefore has a footprint of just 0.02 tonnes of CO_2 equivalent. This means our consumption of natural gas accounts for fully 6.01 tonnes of our 6.03-tonne "house print".

Pharmaceuticals are next on our list. That is probably not typical but I'm diabetic and take several drugs as a result. It seems producing drugs is carbon-intensive.

Third on the list are our two cars. The app asks for year, make, model, and kilometres driven and then tells you how much carbon your driving produces. It says our 2015 Honda CR-V generates 2.34 tonnes while our 2018 Subaru Outback puts out 3.47 tonnes—partly because it is heavier and partly because we drive it more.

Our carbon bill for food and drink comes from entering our overall grocery budget for the year. The "Recreation, cultural and sport" category is a big one

Figure 4: Watson household's carbon footprint (tonnes of CO_2 equivalent)



Source: Author's calculations, using Carbon Footprint, 2021.

for us: we ski and golf, both of which involve lots of energy, whether getting us up the ski hill or manicuring the golf courses we play. This category accounts for 2.71 tonnes of CO_2 equivalent.

I am a little surprised that the "Flights" category does not generate more than 2.37 tonnes. The app allows you to enter three flights per year. That's fewer than we would take in a non-COVID year, but I entered one to Toronto, one to Vancouver, and one southward (for the winter). The "Motor vehicles" entry covers the purchase cost of cars rather than their (already-entered) running costs. We keep our cars an average of 10 years so I amortized their cost over that period. The carbon hit from their capital value presumably is from emissions during the car's construction.

Although my wife and I both maintain a strong interest in education (where I worked and she still does), our own formal education expenditures are minimal, which explains why our carbon emissions from education are also minimal. We also read a great deal but our expenditure on paper reading material, which is what the app asks about, is limited to two newspapers a day and a handful of books per year; most of our book-reading is done on tablets or with paper books borrowed from the local library.

While these calculations may be imperfect for multiple reasons, the results of the exercise are interesting, particularly for addressing the main question: If my wife and I wanted to reduce our carbon footprint by 10%, how would we do it?

It is intuitively appealing to consider an across-the-board cut, such as pulling back on each activity by 10%, as a government might do in reducing its spending. Another intuitive approach would be to focus only on the big emissions. Or on activities most obviously associated with fossil fuels, such as driving and flying. But the important point about the equate-at-the-margin principle is that data on which activities generate our footprint do not actually tell us where we should make cuts. For that, we also need to figure out how much the activities benefit us and therefore how much we would lose by cutting back on them.

Ideally, we should do the 10% cut in whatever way is least costly to us, not just in dollars but in terms of the benefits we get out of the different activities. As established earlier, the environment does not care which CO_2 emissions we reduce—CO_2 is CO_2 is CO_2. So best to do the cutback that causes the least damage to our joint well-being.

In our case, the least costly cutback certainly does not involve a 10% reduction in everything. I would love to be able to cut back on the drugs I take—but I can't: they keep me alive. The cost of any cutback in my pharmaceuticals would be very high. So we'll continue to generate 5.88 tonnes of CO_2 from that category of consumption and really will not be able to do much about it (although perhaps over time drug companies will find less carbon-intensive ways of making the drugs I take). Not being able to get any of the 10% from that category we will have to look elsewhere.

What things can we do? Common on-line recommendations include boiling only the exact amount of water you need for the coffee or tea you're going to make, drying your laundry on the line instead of in the dryer (though that isn't very practical in Quebec in winter), and turning appliances off when you're not using them. We're happy to do the first and third but, as our electricity is generated by hydro, they produce hardly any footprint to begin with.

We could turn down our thermostat and reduce our use of natural gas, which in fact we did, by one degree, in the winter of 2022—but because of rising gas prices rather than concern about carbon. Running the house one-degree cooler does reduce our well-being a little: we have to wear sweaters and thicker socks. But so far the trade-off is not onerous. If we turned the thermostat down another two or three degrees, however, that would involve a more serious reduction in our well-being.

We could put in more insulation though we have already done a fair amount of that, including double-glazing our windows. We could switch over to heating with electricity, although as Quebec is not building any more dams our extra demand on the grid may simply displace other users. We could also think of moving to smaller accommodations, more suited to the two people we are now than the four we were when our children were young. Of course, if we did that, some other family would buy (and have to heat) our current place.

We could take only two flights a year instead of three by either eliminating one trip per year or driving or taking the train to Toronto. It would take longer but would not impinge greatly on our well-being. By contrast, driving or taking the train to Vancouver or to the sun in winter would impose a big cost both in time and in other carbon costs associated with travel.

We could stop subscribing to news*papers* and read them online instead, which we already do with foreign papers and could easily start doing with our local ones, too.

In the end, I am not sure exactly how we would cut our emissions by 10%. But I *am* sure we would follow the "equate-at-the-margin" rule by looking at each possible decrement of a given amount across all our activities and choosing the one that hurts least. We would make that reduction, then ask the same question again and repeat the process until we hit 10%. The general rule is not to have special rules for different activities but to assess how costly cuts are "at the margin", across all your activities. If you can get to 10% without any reduction in your direct fossil fuel consumption—which may be the result if there are no easy heating or transportation substitutes for you—then so be it.

Scaling up the implications of equating at the margin

What is true for a household is not always true for society at large, of course. But the decision-making rule a family should use in reducing its carbon emissions does transfer over to social decision-making: find emission reductions where they are least costly. And do not have special rules (including caps) for different activities. Reductions should come from where they inflict the least damage. Some activities may offer easy reductions to begin with but become very costly at the margin once some cutting has taken place. For example, the cost of keeping oil and gas emissions at 100 Mt CO_2 equivalent may be much greater than the cost of letting them go to 120 Mt and finding 20 Mt of emissions reductions elsewhere.

One difference between a household and the whole society, however, is in how cutting is decided. My wife and I can plan our cuts at the kitchen table. We have what Friedrich Hayek called "the knowledge of the particular circumstances of [our own] time and place" (Hayek, 1945/2018). But all 38 million Canadians cannot sit around one big kitchen table and make a plan for the entire country. Nor can federal officials do it in their place; the detailed knowledge they would require in order to make the right cuts—hundreds of millions of them—verges on infinite. Rather, a central authority can establish a charge for carbon emissions, whether in the form of a tax or an emissions permit, and the rest of us can figure out how to respond to the new constellation of prices that emerges after the charge has raised the relative price of emission-intensive activities. But we will all re-jig our activities in the way that causes us the least harm, and knowledge of exactly how to do that is something only we ourselves have.

The logic of this approach should be clear enough. What may be less clear but is also true is that, if the price signal has been chosen correctly, there is no need to supplement it with further rules and regulations aimed at the same end. The many taxes and subsidies encouraging Canadians to green-this or green-that simply are not needed. Nor should we prejudge the result of our collective response to the price signal by decreeing in advance that certain economic sectors, regions, or activities will have their emissions capped at *x* amount, be that 100 Mt CO_2 or some other predetermined amount.

Endnotes

1. 3.33 bathtubs × 300 litres each = 1,000 litres, divided by 2.5 million litres, equals 400 litres per 1 million litres.

2. Unless otherwise indicated, the data that follow come from this document.

3. A megatonne is one million metric tonnes. A metric tonne is 1,000 kilograms or 2,204.62 pounds.

4. The 2019 level was also lower than the levels in 2000, 2003, 2004, 2007, and 2008. In 2005, emissions were also exactly 730 megatonnes.

5. MIT's climate portal says a tonne of CO_2 would fill a cube 27 feet tall, wide, and long—about the length of a standard telephone pole. The 21.7 of these cubes the average Canadian produced in 2019 would fill almost five Olympic pools (MIT, 2020).

References

Alberta (2016). Oil Sands Emissions Limit Act. Statutes of Alberta, 2016, Chapter O-7.5. Province of Alberta <https://www.qp.alberta.ca/1266.cfm?page=O07p5.cfm&leg_type=Acts&isbncln=9780779814053>, as of June 21, 2022.

Carbon Footprint (2021). *Welcome to Carbon Footprint*. <https://www.carbonfootprint.com>, as of June 21, 2022.

Collaborative on Health and the Environment [CHE] (2016). *Arsenic* (August). <https://www.healthandenvironment.org/environmental-health/environmental-risks/chemical-environment-overview/arsenic>, as of June 21, 2022.

Doconomy AB. (2021). *The 2030 Calculator: A Product Carbon Footprint Calculation Tool by Doconomy. Version 1.0*. <https://www.2030calculator.com>, as of June 21, 2022.

Environment and Climate Change Canada [ECCC] (2021a). *Greenhouse Gas Emissions*. Canadian Environmental Sustainability Indicators. <https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/ghg-emissions/2021/greenhouse-gas-emissions-en.pdf>, as of July 12, 2022.

Environment and Climate Change Canada [ECCC] (2021b). *Greenhouse Gas Emissions from Large Facilities*. Canadian Environmental Sustainability Indicators. <https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/greenhouse-gas-emissions-large-facilities/2021/greenhouse-gas-emissions-large-facilities.pdf>, as of July 12, 2022.

Environment and Climate Change Canada [ECCC] (2022). *Interactive Indicator Maps*. <https://indicators-map.canada.ca/App/CESI_ICDE?keys=AirEmissions_GHG&GoCTemplateCulture=en-CA>.

FTD (2017). *Types of Roses: A Visual Compendium*. FTD by Design. <https://www.ftd.com/blog/share/types-of-roses>, as of June 21, 2022.

Hayek, Friedrich A. (1945/2018). The Use of Knowledge in Society. *American Economic Review / Econlib Books*. <https://www.econlib.org/library/Essays/hykKnw.html>, as of June 21, 2022.

Massachusetts Institute of Technology [MIT] (2020). *How Much Is a Ton of Carbon Dioxide?* Ask MIT Climate (December 2). <https://climate.mit.edu/ask-mit/how-much-ton-carbon-dioxide>, as of June 21, 2022.

National Aeronautics and Space Administration [NASA] (2016). *Following Carbon Dioxide through the Atmosphere*. Goddard Media Studios (December13). <https://svs.gsfc.nasa.gov/12445>, as of June 21, 2022.

Natural Resources Canada [NRC] (2019). *Not Your Average Calculator – Greenhouse Gas Equivalencies Calculator* (June 20). <https://www.nrcan.gc.ca/energy-efficiency/spotlight-energy-efficiency/2019/06/21/not-your-average-calculator-greenhouse-gas-equivalencies-calculator/22147>, as of June 21, 2022.

Rabson, Mia (2021). Trudeau moves on pledge to cap oil and gas emissions as COP26 talks begin in Scotland. *Financial Post* (November 1). <https://financialpost.com/commodities/energy/oil-gas/trudeau-moves-on-pledge-to-cap-oil-and-gas-emissions-as-cop26-talks-begin-in-scotland>, as of June 21, 2022.

United States Environmental Protection Agency [US-EPA] (2016). *Carbon Footprint Calculator*. <https://www3.epa.gov/carbon-footprint-calculator/>, as of June 21, 2022.

Acknowledgments

As the researcher has worked independently, the views and conclusions expressed in this paper do not necessarily reflect those of the Board of Directors of the Fraser Institute, the staff, or supporters. This publication in no way implies that the Fraser Institute, its directors, or staff are in favour of, or oppose the passage of, any bill; or that they support or oppose any particular political party or candidate.

About this publication

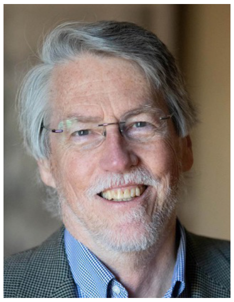
ISSN 2291-8620

Media queries: call 604.714.4582 or e-mail: communications@fraserinstitute.org

Support the Institute: call 1.800.665.3558, ext. 586 or e-mail: development@fraserinstitute.org

Visit our website: www.fraserinstitute.org

About the author



Born and raised in Montreal and educated at McGill and Yale, ***William Watson*** taught at McGill from 1977 to 2017. He was Chair of Economics from 2005 to 2010 and Acting Chair in 2016/17. He is best known for his twice-weekly columns in the *Financial Post* (where he has written since 1980 and where he also edits the FPComment page). From 1998 to 2002, he edited *Policy Options politiques*, the magazine of Montreal's Institute for Research on Public Policy. He is a Senior Fellow at the Fraser Institute, for which he blogged weekly from 2015 to 2019 and has written a number of publications, the first in 1988. While on a leave from McGill in 1997/8 he served as editorial pages editor of the *Ottawa Citizen*. He won the 1989 National Magazine Awards gold medal for humour for a piece in *Saturday Night* magazine about a trip to New York. His book, *Globalization and the Meaning of Canadian Life*, published by the University of Toronto Press, was runner-up for the Donner Prize for best book on Canadian public policy of 1998. His most recent book, *The Inequality Trap: Fighting Capitalism instead of Poverty*, also from UTPress, was shortlisted for the National Business Book Award 2016.