Carbon and curriculum

Towards evidence-based climate change education in Canada

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Seth Wynes

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Supervisor: Kimberly Nicholas, LUCSUS, Lund University

Abstract:

Despite an overwhelming scientific consensus that climate change is a threat to our society, many young Canadians do not view it as a major issue. This suggests flaws in the way that youth are educated on climate change. I therefore investigated climate change education in Canada to recommend improvements.

I analyzed Canadian secondary science curricula according to two frameworks to determine how thoroughly climate change is addressed. Results showed that Canadian provinces provide more comprehensive coverage of climate change than American states (70% of Canadian provinces give the highest level of coverage compared to 10% of American states). In general, learning objectives in Canadian provinces tend to focus on knowledge of climate change with little or no emphasis on scientific certainty or ways to address the issue.

These results led me to conduct interviews with six individuals responsible for curriculum design in different provinces to see how documents are developed and whether political controversies influence the writing process. Interviewees described a development process relying on input from professionals, institutions and members of the public that is free of political interference. In some cases, efforts to remain neutral on this controversial subject may have led to descriptions of social controversy where there is actually scientific consensus on climate change.

Following a review of current literature, I evaluated a list of potential behaviours to find the most effective ways to reduce an individual's carbon footprint. The four high-impact actions I identified were: have fewer children, avoid air travel, live car free, and eat a plant-based diet. I then analyzed ten Canadian science textbooks to see which types of personal behaviours are currently recommended to students for reducing their carbon footprint. Textbooks encouraged low- or medium-impact behaviours such as recycling and household energy conservation, but rarely or never mentioned high-impact actions. While avoiding air travel can be 15 times more effective than recycling, it was mentioned one-fifth as frequently. This is problematic given the difficulty of meeting the 3.3 tonnes per capita reduction required by Canada's current CO_2 emissions target using low-impact actions.

I suggest that if Canadian students are to be prepared for climate change, they should receive educational content that is consistent with evidence and delivered in the most effective ways. In line with this evidence-based approach, I prepared high school teaching materials that encourage the adoption of high-impact actions, using strategies suggested by studies of environmentally motivated behaviours.

Keywords: climate change education, high school, Canada, carbon footprint, individual

Word count: 13 942

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Abbreviations

BEV – Battery electric vehicle

CO_2e – Carbon dioxide equivalents

GHG – Greenhouse gas

IPCC – Intergovernmental Panel on Climate Change

LCA – Life cycle assessment

NGSS – Next Generation Science Standards

SUV – Sport utility vehicle

1 Introduction

1.1 An overview of climate change

2014 was ranked as the hottest year on record, continuing a pattern where fourteen of the warmest fifteen years have fallen in this new century (WMO, 2015). This upward trend in warming is due to the human production of greenhouse gases (GHGs), and is part of the larger process of climate change. The Intergovernmental Panel on Climate Change (IPCC) catalogues some of the risks associated with a rise in global mean temperatures of 4°C, which include,

> …severe and widespread impacts on unique and threatened systems, substantial species extinction, large risks to global and regional food security, and the combination of high temperature and humidity compromising normal human activities, including growing food or working outdoors in some areas for parts of the year (high confidence). (IPCC, 2014b)

To paraphrase in less academic terms, if global society does not alter its collective behaviour, the world faces the risk of mass animal extinction, mass starvation and temperatures that would fundamentally alter the way we live.

The Government of Canada supports an aggressive approach to climate change that achieves environmental and economic benefits for all Canadians (Environment Canada, 2014b). The Ontario Minister of the Environment and Climate Change went further and declared that climate change is "the critical issue of our time" (MOECC, 2015). Yet there seems to be a gap between what the government says and what the people believe. Only 63% of Canadians believe that "the science is conclusive that global warming is happening and caused mostly by humans"[1]. That figure increases to 67% when considering the age category of 18-24[1]. But seven years ago the vast majority of that demographic were school students, and should have received education on climate change as part of compulsory schooling (McMullen and Gilmore, 2010). In that same demographic, 54% claimed to be either "somewhat concerned", "not very concerned" or "not at all concerned" about changes in our

[1] This analysis if based on the Environics Institute for Survey Research Microdata file, *Focus Canada 2014: Detailed Data Tables*, which contains anonymized data collected in the Focus Canada 2014 Survey. All computations on these microdata were prepared by Seth Wynes and the responsibility for the use and interpretation of these data is entirely that of the author.

climate due to global warming[1]. It stands to reason that education in Canada has not adequately convinced young people of the scope and urgency of this issue.

The context of the problem can therefore be summarized as this: climate change poses huge risks to humanity which are recognized both by scientists and the Canadian government, and yet even those Canadians who have received formal education on climate change often show ambivalence on the subject.

1.2 The scientific understanding of climate change

Before comparisons can be made between education and the latest scientific understanding of climate change, we must first investigate what scientists generally agree upon in this subject area. I therefore begin the discussion with a highly regarded authority, the Intergovernmental Panel on Climate Change. The IPCC was formed by the United Nations Environment Programme and the World Meteorological Organization in order to provide information that could assist nations in making decisions regarding climate change (InterAcademy Council, 2010). The Physical Sciences aspect of the IPCC report features 600 authors whose drafts were subject to two rounds of formal review, as well as a round of government comments (Stocker et al., 2013). Furthermore, a total of "54,677 written review comments were submitted by 1089 individual expert reviewers and 38 governments" (Stocker et al., 2013). Using this extensive review process, the IPCC found that "It is extremely likely[2] that human influence has been the dominant cause of the observed warming since the mid-20th century" (IPCC, 2014a). Still, due to political controversy around this process, the InterAcademy Council was asked to review the IPCC's methodology and, while making suggestions to keep the IPCC up to date with changes in science and politics, still described the process as "successful overall" (InterAcademy Council, 2010). To summarize, the IPCC makes use of a rigorous peer review process which has concluded that the climate is warming and that this warming is caused by human actions. This constitutes the primary basis for the idea that a scientific consensus exists on this subject.

Beyond the IPCC, other researchers have quantified the level of agreement within the scientific community. In an early study of climate change beliefs in the scientific community, Oreskes (2004) analyzed 928 refereed journal articles with the keyword "climate change", and found that none explicitly rejected the consensus view that humans were causing climate change. Later, a larger study of 11 944 peer-reviewed climate science abstracts found that of those papers which expressed a view on anthropogenic climate change, 97% supported the view that humans are causing climate

[2] According to IPCC's own definition, "extremely likely" indicates a 95-100% likelihood of an outcome (Stocker et al. 2013).

change (Cook et al., 2013). Other studies show that the level of agreement on the subject of anthropogenic climate change increases with the level of expertise on the subject (Anderegg, Prall, Harold, & Schneider, 2010; Doran & Zimmerman, 2009). Put another way, those who remain unconvinced by the evidence of anthropogenic climate change tended to be less credible in the field of climate science. These studies also confirmed the figure of ≈97% of climate scientists supporting the concepts of anthropogenic climate change found by Cook et al. (2013).

Additionally, Oreskes (2004) pointed out over ten years ago that all major, relevant scientific bodies within the US have released statements similar to the findings of the IPCC (2004). For instance, the American Geophysical Union released a statement that "Humanity is the major influence on the global climate change observed over the past 50 years" (AGU, 2013). The American Association for the Advancement of Science agrees, saying "The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society" (AAAS, 2006). The combination of support for anthropogenic climate change from the IPCC, independent climate scientists and numerous scientific bodies suggests that there is no longer debate in the scientific community; as far as climate researchers are concerned, the earth is warming and that warming is driven by human behaviour.

1.3 The goals of climate change education

The Ontario government document, *Shaping Our Schools Shaping Our Future* says that environmental education "seeks to promote an appreciation and understanding of, and concern for, the environment, and to foster informed, engaged, and responsible environmental citizenship" (Bondar, 2007). But what is a responsible environmental citizen? Is it someone who engages their political representatives on environmental issues? Or is it perhaps an informed and conscientious consumer? Climate change education would contribute to both of these definitions, and seems to fall within the larger frame of environmental education. Certainly informed environmental citizenship in this time period requires some understanding of climate change. For instance, scientists are currently debating the merits of different geoengineering schemes (Biello, 2014; Boyd, 2008). Should any of these issues ever reach a point of policy implementation, it would be desirable to have a general public that is capable of making informed decisions on the topic.

Beyond the creation of an informed citizenry, climate change education might be said to have a normative goal. In Ontario, health and physical education courses have the normative goal of instilling the habit of daily physical activity (MEDU, 2015). Similarly, climate change education could

be assigned the goal of increasing sustainable behaviour and environmental action amongst students.

I suggest that climate change education should include literacy on climate change issues, engagement in the political processes related to climate change, and understanding of responsible behaviour. In this paper I identify how we currently attempt to accomplish these goals, and how revisions could be made to achieve them.

1.4 Climate change education and sustainability science

From the overview of climate change education seen above, some connections between education and sustainability science are already evident. UNESCO's 2013/14 Global Monitoring report says,

> By improving knowledge, instilling values, fostering beliefs and shifting attitudes, education has considerable potential to change environmentally harmful lifestyles and behaviour. A key way in which education can increase environmental awareness and concern is by improving understanding of the science behind climate change and other environmental issues. (UNESCO, 2014)

The United Nations believes that education has a role to play in addressing these issues, which have been described as receiving special attention in recent years (Clark, 2007). And since sustainability science is "defined by the problems it addresses rather than by the disciplines it employs" (Clark, 2007), it would seem that education on the topic of climate change would qualify as a relevant aspect of this field. Parts of this thesis involving educators were also transdisciplinary in nature (in that they involved collaboration with non-academic actors) which is an emerging hallmark of sustainability science (Lang et al., 2012).

1.5 Science education in Canada

Canada is divided into ten provinces and three territories each of which controls its own educational system. Because of this division, education can vary between the provinces, resulting in different curriculum documents, standardized tests, teacher education programs and so forth. Within these educational systems, science is split into 'silo' subjects; chemistry, biology and physics are common, while earth and space science or environmental science are less likely to be present at all grade levels. Teachers at the secondary level are subject specialists, meaning they are trained to teach a few specific subjects, rather than all of the subjects. Even amongst science teachers, some are qualified to teach chemistry, but not biology or physics (as an example).

In this paper I discuss how climate change education is delivered in this unique context, noting areas where educational practice is firmly supported by scientific evidence and where it is not. I also make recommendations for changes that could be made without the need for greater alterations in the educational system.

2 Research design and methods

The overarching question that this study attempts to answer is: how can climate change education be improved in Canada? In order to accomplish this, several more specific questions are delineated in Table 1 below.

Table 1: Broad themes, research questions and methods for this thesis.

Broad themes	Research Questions	Method
1. Do the science curricula of Canadian provinces align with the latest scientific understanding of climate change?	1. How do Canadian provinces compare to American states in their treatment of climate change?	Curriculum analysis
	2. How thoroughly do provincial curricula cover the subject of climate change?	Curriculum analysis
	3. How are curricula developed in the different provinces?	Semi-structured interviews
2. What would evidence-based climate change education in Canada look like?	4. What high-impact actions should be recommended for individual emissions reductions?	Literature based research
	5. Are high-impact actions already recommended in science textbooks?	Textbook Analysis

2.1 Science curricula of Canadian provinces

2.1.1 Curriculum Analysis

Research Question 1: Curricular comparison between Canada and the United States

Curriculum documents were downloaded from government websites for all ten provinces (territories rely on curriculum documents developed in certain provinces). Word searches were conducted for “climat”, “glob”, “warm”, “temp”, “greenho” “gases”, “anthro” and “human”, following the protocol of Golden and Francis (2014). Initially I analyzed the curricula according to a framework employed by Golden and Francis (2014) for standards in the United States, which involved assigning a score of 0 to

4, with 0 representing no climate change coverage and 4 representing a thorough treatment of the topic (Table 2).

Research Question 2: Provincial coverage of climate change

It became clear that the Canadian provinces had much more rigorous standards in terms of climate change, and that while this framework would be useful for a comparison to the United States, it would not be as useful for comparing one province to another (for instance, no Canadian provinces scored in the category 0, or 1, whereas many states fell into both of those categories). I therefore employed an additional framework developed by Nicholas et al. (2014). In this framework, relevant learning objectives were grouped into six core topics which are associated with statements from the latest IPCC report (Nicholas et al., 2014). Understanding of five of the six topics has also been associated with pro-environmental behaviour regarding climate change (Ding et al., 2011; Krosnick et al., 2006). The topics include: foundational climatic knowledge (It's climate), observations and proxies of rising temperature (It's warming), anthropogenic contributions to climate change (It's us), the scientific process of obtaining consensus (We're sure), the various impacts associated with climate change (It's bad), and the approaches and policies that can be used for mitigation (We can fix it).

Learning objectives were not included if climate change was referenced as one of several possible examples. For instance, in the Ontario science course SNC4M the learning objective E3.3 says, "explain the impact of various threats to public health, including infectious diseases (e.g., hepatitis, HIV/AIDS, tuberculosis, malaria, sexually transmitted diseases), chronic diseases (e.g., cardiovascular disease, diabetes, asthma), and environmental factors (e.g., climate change, air pollution, chemical pollutants, radiation)" (MEDU, 2008b). Although climate change is listed as a threat to public health, which would qualify as a statement that could be categorized "It's Bad" category, because a teacher could choose many other examples to meet the objective instead, it does not qualify. Similarly, if climate change was mentioned in supporting documentation (suggested resources, optional activities etc.) it was not counted towards any of the categories. Lastly, I noted when a course was mandatory for graduation from secondary school or merely optional.

2.1.2 Interviews with curriculum contributors

Research Question 3: Curriculum development in the different provinces

In order to gain a better understanding of what makes the provincial curricula so different from one another, contributors to each province's science curriculum were contacted and asked to participate

in interviews. In total six interviews were conducted with contributors to six different provinces' science curricula. Interviewees included both contributing teachers as well as science consultants. The interviews were semi-structured, with questions provided beforehand to encourage thoughtful responses to questions that were difficult or referred to events that took place several years in the past. Written informed consent was obtained prior to all interviews (Appendix A).

One explanation for provinces having dissimilar approaches to climate change is that political differences between provinces result in different outcomes. Interviewees were therefore asked if the controversial nature of climate change affected the writing process. Additional questions explored other possibilities for why provinces have such varying coverage of climate change, such as the use of particular government documents, the way in which curriculum writers are selected, the time period in which the curriculum was written, and the overall curriculum design process (Appendix A).

The interviews tended to last approximately thirty minutes, and were conducted via telephone or Skype depending on the preference of the interviewee, with one interviewee choosing to respond in written form. Interviews were recorded and then transcribed with pseudonyms and with identifying information removed. Transcripts of the interviews were provided to the interviewees and those parts which would be used as quotations in the final publication were indicated separately.

Thematic analysis was used to analyze the interview transcripts, according to guidelines provided by Bryman (2008). Following transcription of the recordings I tentatively identified themes that seemed common in the interviews. Some themes were simply straightforward responses to questions which I asked (such as whether controversy on the subject of climate change affected the curriculum design), while other were unsolicited ideas such as the need to teach about sustainability. I arranged the themes as rows in a spreadsheet and pasted relevant interviewee quotations into adjacent columns. Seeing how many of the interviewees actually responded in similar ways to the same question or mentioned similar themes without prompting gave an indication of which trends or practices were more salient in the curriculum design process.

2.2 What is evidence-based climate change education?

2.2.1 A review of the current literature

Research Question 4: High-impact actions

As many curriculum designers and government documents referred to individual actions as being central to climate change mitigation (Discussion), I investigated which actions would be most

effective at reducing an individual's carbon footprint (the quantity of greenhouse gases that can be attributed to an individual, as measured in carbon dioxide equivalents (CO_2e)). For reference, the average Canadian produces between 14 and 20 tonnes of CO_2e, depending on accounting methods (Boden et al., 2013; Environment Canada, 2014a).

To determine if the individual actions suggested by teachers and students to mitigate climate change were consistent with evidence regarding their effectiveness, I attempted to partition individual actions into high- and low-impact categories. While "short lists" have been published for the most effective actions at reducing an individual's water footprint (Inskeep and Attari, 2014), or household energy use (Gardner and Stern, 2008b), as far as I am aware there have been no similar lists produced for an individual's overall carbon footprint. Similarly, in educational material, when suggestions for individual actions are provided by agencies or governments, they tend to be in "laundry lists" without any indication of whether one action is more effective than another. By compiling my own list I not only aim to fill a gap in the literature, but also provide a useful set of "high-impact" actions which can be passed on to students. This follows the practice suggested by Gardner and Stern (2008b) who adopt the common public health strategy of communicating a small number of focused actions.

In order to find my short list, I generated a list of actions by reading through suggestions found in science textbooks and through discussions with colleagues. Some actions, such as purchasing a new car with better mileage, can be seen in one way to reduce emissions (less carbon dioxide produced per mile driven), but could possibly lead to a net increase in an individual's carbon footprint because of emissions generated upstream during the manufacturing process (Jones and Kammen, 2011; Kagawa et al., 2013). Since I wanted a list that could be given to students and offer clear and effective measures for reducing their carbon footprints, actions of such debatable merit were removed from the list. Similarly some actions were of relatively high consequence if implemented to a large extent, such as replacing every incandescent lightbulb in a house with an LED. However these were considered less valuable if the improvement was seen as inevitable. In this case, government regulations in many developed countries are phasing-out incandescent light bulbs (European Commission, 2009; NRC, 2014), so it is less sensible to focus on this effort.

Each action was ranked according to the CO_2e per year that would be reduced should a specific action be taken. I relied primarily on peer-reviewed literature for the numbers that informed my ranking, but occasionally used carbon calculators (for example, to calculate air travel emissions). When possible, data was taken from North American sources so that the results applied best to the target audience of Canadian students, but other sources from the developed world were also used,

which make the results more generalizable. Some data was adjusted so that all units were equivalent, and in some cases extra calculations were needed to find the correct units. For instance, in the case of emissions from pets, I relied on a Life Cycle Assessment of dog food, and calculated the average food intake of different breeds based on veterinary journal articles. Full calculations are available in Appendix B: Calculations.

Actions that were chosen for the final short list all have the potential to reduce an individual's emissions by at least 1 tonne per year, depending on the scenario in question, and present minimal chance of a strong rebound effect. Actions were also chosen based on the reasonable likelihood of an average person participating in them. For instance, although purchasing a yacht might have higher emissions than a sport utility vehicle (SUV), only the SUV was considered.

Four actions that were hypothesized to be of relatively high-impact were proposed to an expert group consisting of five PhD students, two post-doctoral students and three professors from a sustainability science department at Lund University (the Lund University Centre for Sustainability Studies). In order to gauge if there was intuitive support among experts for labelling these measures as "high-impact", each expert was asked to choose between a low-impact action and a high-impact action with approximately ten times the emissions reduction potential, based on various studies. These actions included: switching from an omnivorous to a vegetarian diet, avoiding air travel, not owning a car, and having fewer children. The sustainability scientists showed 95% agreement (38/40 responses) in identifying a high-impact action when paired with a relatively low-impact action.

To further establish the legitimacy of these four actions, I compiled a spreadsheet containing data values for the CO_2e of each action (which required some calculations from the source material). Data values were obtained either from peer reviewed literature (especially Life Cycle Assessment (LCA) studies) or carbon calculators. Studies which themselves compared the magnitude of different actions were also included (Eshel and Martin, 2006; Murtaugh and Schlax, 2009). Studies for dietary comparisons were selected based on those that best exemplified a realistic switch from an omnivorous diet to a vegetarian or vegan diet. For this reason certain scenarios, such as the indiscriminate replacement of all meat-based calories with fruit and vegetables (Vieux et al., 2012) or with dairy products (Berners-Lee et al., 2012) were not included.

In terms of personal vehicles, most studies list climate change impact in gCO2e/km, and also provide a lifetime of the vehicle in km. I assumed 15200km driven per year based on a Canadian average (NRC, 2008) to determine the tonnes of CO_2 produced per year, unless another value was specified in the paper. As my unit of analysis was a single individual, I also divided the tonnes of CO_2 produced

per year by the average vehicle occupancy of 1.55 for cars and 1.9 for SUVs (Davis et al., 2014). Data from the United States were used in this case as Canadian statistics aggregates SUVs, vans and pickup trucks, however the figures are similar, as Canadian vehicles have an average occupancy rate of 1.62 overall (NRC, 2009). Later in the paper I make comparisons with other actions, some of which involve household behaviours or efficiency improvements. These are also divided by the average number of occupants per household in the United States, 2.63 (United States Census Bureau, 2015). This figure was chosen as much of the comparisons are from Gardner and Stern's paper (2008) from the United States.

LCAs differed in their scope and methodologies, and while I attempted to focus on those with the most comprehensive coverage of the lifecycle, I also wanted to include a variety to demonstrate the range of potential impacts that could be produced by these actions. Similarly, though Padgett et al. have identified issues in the differing results of carbon calculators (2008), by obtaining data from a variety of carbon calculators I hoped that the range of impacts would help ascertain whether these actions qualified as "high-impact". A full list of the sources for these data can be found in Appendix B: Calculations.

2.2.2 Are students already receiving evidence-based education on climate change?

Research Question 5: High-impact actions in science textbooks

When the short list of high-impact actions was completed I examined ten Canadian textbooks to see how many of the high-impact actions were already suggested in these government recommended textbooks. Through this process I hoped to gain an understanding of whether students are encouraged to undertake more high or low impact actions. Ten textbooks (seen in Figure 3) used in seven Canadian provinces were analyzed. Difficulties in obtaining certain texts used by the provinces of Alberta, Manitoba, and Nova Scotia prevented analysis of texts representing those areas, while the three territories make use of provincial resources.

Textual statements were identified as suggested actions when they included direct recommendations or were directed at the reader, using pronouns such as "you" or "us", instead of generalizations such as "individuals" and "consumers" which reference the source of emissions without offering suggestions. For instance, the statement, "Some of the largest demands for energy come from industries (to produce goods) and individuals (to light, clean, heat and cool homes, cook food, and operate cars) (Sandner et al., 2009)" is not taken as a suggestion to reduce lighting needs or drive less frequently, whereas the statement, "You may also choose to purchase carbon offsets to minimize your carbon footprint (Dickinson et al., 2009)" is taken as a suggestion.

For each textbook I recorded the frequency of each type of suggestion. In my coding system, a single sentence referring to a specific topic was given the same frequency as a paragraph devoted to a single topic. If a paragraph on a broad topic (e.g. household heating) included many specific suggestions (turn down thermostat, purchase a more efficient heater) then each specific suggestion was counted towards the total. Only the textbook chapters directly addressing climate change were analyzed.

As it became evident during the research process that textbooks were not addressing these four high-impact actions, I created a set of resources specifically tailored towards them. The resources included four fact-sheets, a PowerPoint presentation, and teacher instructions on how to implement the resources in a lesson. I based the material for the fact sheets on studies which investigated the most persuasive ways to encourage certain behaviours, such as eating a plant-based diet. I was not able to find studies for all of these actions, and therefore followed general principles used to encourage environmentally friendly behaviour as found in other research. The resources were also presented to secondary students and teachers in both Canada and Sweden, and modified according to their feedback.

3 Results

3.1 Climate change curricula

3.1.1 Research Question 1: Curricula comparison between Canada and the United States

According to the framework of Golden and Francis (2014), no provinces received a score of 0 or 1, meaning that all Canadian province explicitly addressed climate change in some way (Table 2). According to this framework, most provinces scored a 4, which indicates that they not only addressed anthropogenic climate change but did so in a section of curriculum that was dedicated to climate change.

Table 2: Coverage of climate change in provincial secondary science curricula scored according to the framework of Golden and Francis (2014).

Score	Score criteria, according to Golden 2014	Provinces/Territories
0	No explicit mention of climate change or global warming	0
1	Climate change/global warming are mentioned in a cursory way	0
2	Some detail on climate change/global warming, no explicit mention of human causation	New Brunswick Nova Scotia
3	Detailed treatment of climate change/global warming including an anthropogenic element	Manitoba
4	Detailed treatment of climate change/global warming, including an anthropogenic element, within one or more standards explicitly devoted to the concept	Alberta British Columbia Newfoundland and Labrador Northwest Territories Nunavut Ontario Prince Edward Island Quebec Saskatchewan Yukon

3.1.2 Research Question 2: Provincial coverage of climate change

The framework of Nicholas et al. (2014) helped to further differentiate the provinces from one another. The categories “We can fix it” and “We’re sure” were underrepresented in the various curricula, while every province covered “It’s Climate” (Table 3). The table also shows that several provinces only covered climate change in non-mandatory courses.

Table 3: An analysis of secondary science curricula for the various Canadian provinces**,** showing which categories in Nicholas' framework (2014) have been covered and in what manner. Refer to Appendix C: Curriculum Analysis for further details. ✓✓=found in a mandatory course, ✓ = found in a non-mandatory course, / = found in an optional unit

Province	Number of secondary students *(most recent available data)*	It's climate	It's warming	It's us	We're sure	It's bad	We can fix it	Total
Alberta	210405[3]	✓	✓	✓		✓		4
British Columbia	635057[4]	✓✓		✓✓		✓✓		3
Manitoba	65802[5]	✓✓		✓✓		✓✓		3
New Brunswick	34046[6]	✓✓		/		/		1
Newfoundland and Labrador	22241[7]	✓✓	✓✓	✓		✓	✓	5
Northwest Territories	3105[8]	✓	✓	✓		✓		4
Nova Scotia	60899[9]	✓✓						1
Nunavut	2907[8]	✓	✓	✓		✓		4
Ontario	662448[10]	✓✓	✓✓	✓✓		✓✓	✓✓	5
Prince Edward Island	7188[11]	✓✓	✓	✓		✓	✓	5
Quebec	194187[8]	✓✓	✓	✓✓		✓	✓	5
Saskatchewan	54027[8]	✓✓	✓✓	✓✓	✓	✓✓	✓✓	6
Yukon	2033[12]	✓✓		✓✓		✓✓		3
Total		13	8	11	1	11	5	

The table also shows that Saskatchewan and Ontario had the most comprehensive coverage of climate change with five of the six categories covered in mandatory courses. New Brunswick and

[3] Alberta Education, (2014) Breakdown of Alberta Student Population, Statistics. Government of Alberta.
[4] MOEd, B., (2014) Student Statistics - 2013/14, in: Education, M.o. (Ed.), p. 9.
[5] MEAL, (2013) Enrolment Report, in: Learning, M.E.a.A. (Ed.), Winnipeg, Manitoba.
[6] DEECD, (2014) Summary Statistics: School Year 2013-2014, in: Development, D.o.E.a.E.C. (Ed.).
[7] DEECD, (2013) Enrollment Information, in: Development, D.o.E.a.E.C. (Ed.), p. 3.
[8] Canada, S., (2014b) Table 477-0025 - Enrolments for regular programs for youth in public elementary and secondary schools, by grade and sex, Canada, provinces and territories, annual (number). Statistics Canada.
[9] EECD, (2012) 2012-13 Enrolments by Board and Level.
[10] MEDU, (2014) Education Facts, 2013-2014 (Preliminary). Queen's Printer for Ontario, Toronto.
[11] DEECD, (2012) Prince Edward Island Enrolment Statistics, in: Development, D.o.E.a.E.C. (Ed.).
[12] Education, Y., (2015) Enrolment Reports 2014/2015, in: Assessment, S.I.a. (Ed.), Whitehorse, Yukon.

Nova Scotia had the least comprehensive coverage with only “It’s Climate” addressed in mandatory secondary school courses. Although there are fewer differences between Canadian provinces than between American states, there is still a wide disparity between those provinces with the most and the least comprehensive coverage of climate change.

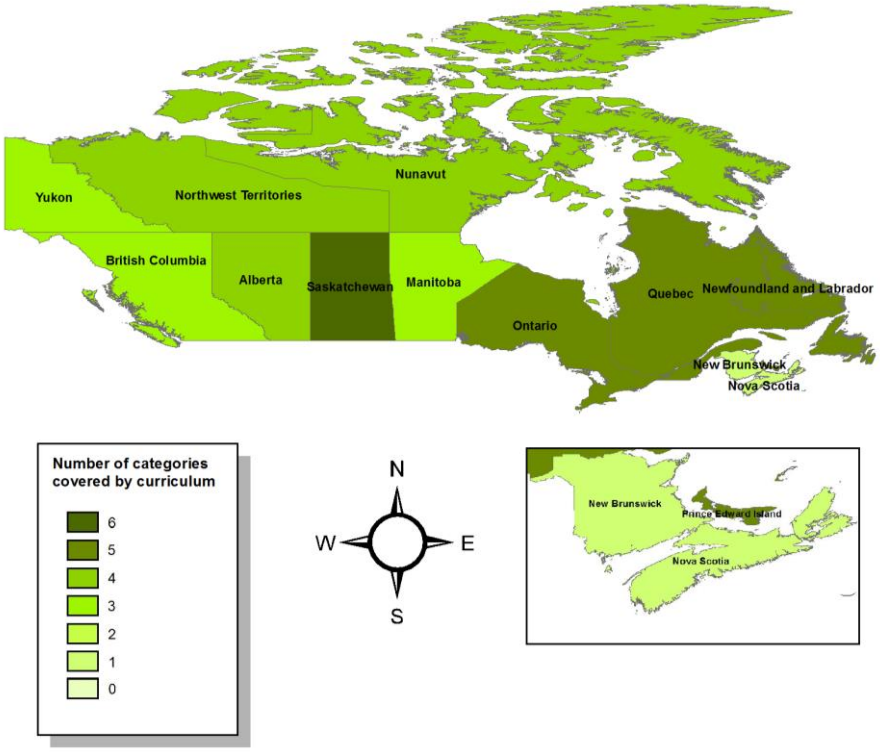

Figure 1: A map showing provincial coverage of climate change, with data from Table 3. The map presents no clear geographic trends in the way that different provinces cover climate change. It should also be noted that size does not correlate with population in Canadian provinces, and that there are large disparities in the number of inhabitants of different regions (information of student population size is available in Table 3).

3.1.3. Research Question 3: Curriculum development in the different provinces

Three male and three female interviewees, from six different provinces, with a range of 8 to 35 years of experience in education participated. Interviews with individuals who contributed to the development of different curricula pertaining to climate change across the provinces of Canada revealed moderate differences in the development process that appear to be responsible for the variance between provinces on the topic of climate change (as opposed to external factors such as political input).

According to interviewees, the process for selecting individuals to contribute to curriculum design varied from several different formal application processes to recommendations from school boards to hiring due to circumstance. This could introduce an element of randomness that would partially

explain some interprovincial disparities, especially as one interviewee commented that "…it's really the luck of the draw who ends up on a committee and what they're interested in can absolutely, totally change the direction of what a course might be." Although there is a larger framework, called the Common Framework of Science Learning Outcomes K to 12 which provides guidance (Council of Ministers of Education, 1997), some provinces rely on it more than others, and one interviewee noted that it provides little detail beyond grade 10.

Numerous factors influence how much space in the curriculum is given to climate change including: feedback from teachers; input from university faculties of education, researchers and environmental groups; the approaches taken by other provinces and jurisdictions; and the availability of teaching resources for the subject (textbooks etc.). While interviewees acknowledged that climate change can be politically controversial, and that pressures are applied from government officials, NGOs and the public, no interviewee described direct interference in the curriculum writing process (Box 1).

Box 1: Interviewees on the topic of addressing external pressures when designing curriculum documents

Me: Politically, climate change is a very controversial topic. Did that influence the approach taken to writing parts of the curriculum that related to climate change?
Interviewee 4: …politics doesn't influence when it comes to that aspect of it. That aspect of writing curriculum.

Interviewee 1: We weren't being told by the government - we had a lot of freedom with the document.

Interviewee 2: There wasn't really a place to go that said, "This is a good thing to do". There certainly wasn't any pressure at any government level to say, "You must incorporate climate change in your curriculum".

Interviewee 2: So we do get questions asked a lot from the Ministry of the Environment, but no direction.

Interviewee 3: It can weigh into our considerations if we have groups come forward and exert pressure to include certain areas in the curriculum. But we really look for a balanced approach to the curriculum.

Me: Politically, climate change is a very controversial topic. Did that influence the approach taken to writing the curriculum on climate change? If so, how?
Interviewee 5: No, Climate change was included as a factual component of the curriculum based on the recommendation from Shaping Our Schools Shaping Our Future the report of the working group on Environmental Education.

Interviewee 6: …but nobody tells us that you have to teach this. But on the other hand there are so many, many groups that want you to teach what they want. Like…
Me: NGOs?
Interviewee 6: Environmental groups, yeah, NGOs. So many of all kinds, that want you to teach whatever, that don't understand why you're not doing x, y or z. Not just for science, for everything. But certainly for all the sciences also.

Instead, five of the six interviewees made comments about how documents in other jurisdictions and provinces can influence the curriculum writing process. Often, a scan of educational materials from other locations was one of the first steps mentioned in the development process. As an example of this interprovincial relationship, the science consultant for Saskatchewan described a conversation

with colleagues from another province about a progressive change in senior science curriculum: "every single one of them said, "well we'd never pull this off in our province politically, but if you can get it going in Saskatchewan then we might be able to afterwards"." Overall, in the Canadian context, external influence is minimal, but change in one province may give momentum to other provinces considering change in the same direction.

Another recurring theme amongst curriculum developers was the belief that educators had a responsibility to dispassionately provide students with information or that students needed to be trained to evaluate the issue of climate change for themselves (Box 2).

Box 2: Curriculum developers on a balanced approach to climate change education

Interviewee 1: So is it, is it a political issue? Yeah, absolutely. How you deal with it – it has to be a very balanced approach.

Interviewee 1: Like I said, you basically have to be fence-sitting even if you're very passionate about these issues. And I know that it's probably not that easy with some teachers, and it's probably not even always easy with me on some issues because I get so passionate about them. I, you know, I weigh in on it. But at the end of the day it has to be a very neutral approach otherwise you're going to introduce a bias into all of these documents that you've put together.

Interviewee 2: I think we've sort of minimized the concern out there, and I'm sure there's some groups would like a little more on climate change. But again, I'll say to them, "Our job's to open the door to talk about it, our job isn't, and our job as teachers isn't to say climate change is good or bad, right?" It's to say, "We want students to understand how scientists develop the information that they do".

Interviewee 3: …so I think that, yes, the fact that people can have strong interests and can try to sway individuals for favour, for power, for money or whatever—we want students to be able to have the skills to be able to sift through information and make informed decisions that will enable them to survive better and flourish.

Interviewee 4: I always tell my students, I may share my opinion, but it's nothing more than, and I never ask them to agree with me. In fact, I would prefer for them - my goal is to say, "this is just one more piece of information that you have got to verify and agree or disagree with".

3.2 What is evidence-based climate change education?

3.2.1. Research Question 4: High-impact actions

Four high-impact actions were identified as the most effective in terms of decreasing an individual's emissions: having fewer children, avoiding air travel, living car free and eating a plant-based diet. Each action has the possibility of reducing a person's impact by at least one tonne of CO_2 per year, should result in minimal rebound effects, and represents a widespread behaviour in the Canadian context. The range of potential climatic impacts of my recommended action can be seen in Figure 2.

I also investigated a fifth potential high-impact action regarding the impact of dog ownership. Dog ownership certainly has the potential to be a high impact action for some people. If an individual owns a large breed of dog alone, then the carbon footprint attributable to them from the dog could be as high as six tonnes of CO_2e per year. However, given the assumption that most people share a pet (which reduces its per capita magnitude) and the limited data available on this topic I do not suggest it as a high-impact action at this point.

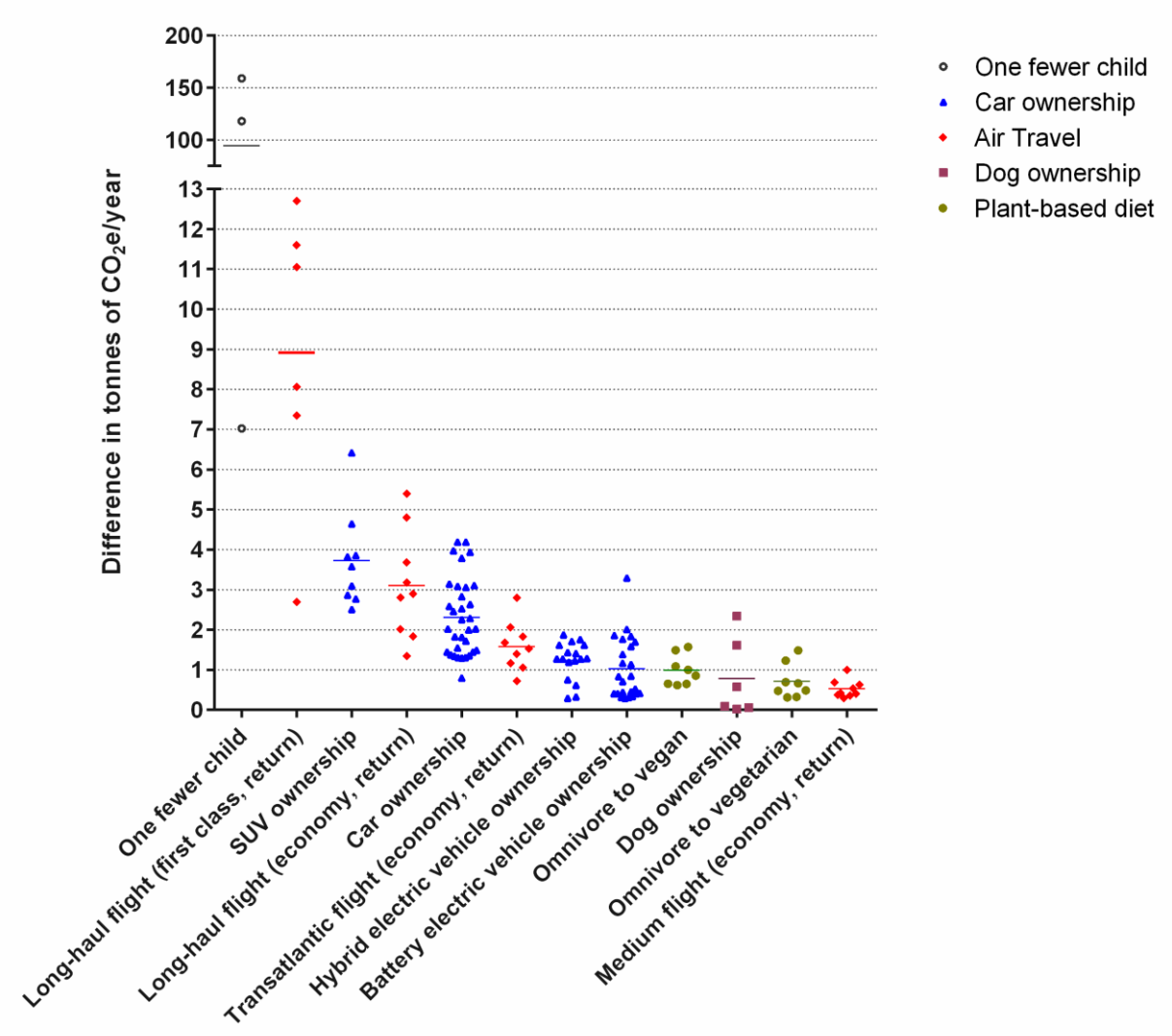

Figure 2: Potential emissions reductions of the high-impact actionsas measured in tonnes of CO_2 equivalents per year. A list of sources is available in Appendix B: Calculations. For SUVs and cars only internal combustion models were included. Cars represent vehicles ranging from compact to family size. Flight data is based on an average of values found by carbon calculators, with radiative forcing applied when the option was given. The long-haul flight is based on London to Hong Kong, the transatlantic flight is based on New York to London, and the medium flight based on Toronto to Orlando. Dog ownership is based on two LCA studies of dog food with scenarios chosen for three different, representative breeds. Mean values are indicated by a horizontal line. Note the break in the y-axis.

3.2.2. Research Question 5: High-impact actions in science textbooks

Analysis of textbooks showed that very few of the identified high-impact actions were addressed in textbooks. No textbook suggested having fewer children as a way to reduce GHG emissions at all while avoiding air travel was rarely mentioned. Eating a plant based diet was only suggested in the form of compromises such as eating less meat, even though a completely plant-based diet can be 2 to 4.7 times more effective at reducing emissions than diets that simply reduce meat intake (Meier and Christen, 2012). Similarly, while there were many statements for ways to reduce one's impact while driving, such as "reduce how far and how often we drive" (Barnes et al., 2009), there were fewer statements that suggested the larger scale change of not owning or driving a car at all. Thus, the few times that high-impact actions were suggested, they were presented in a diluted form (Figure 3).

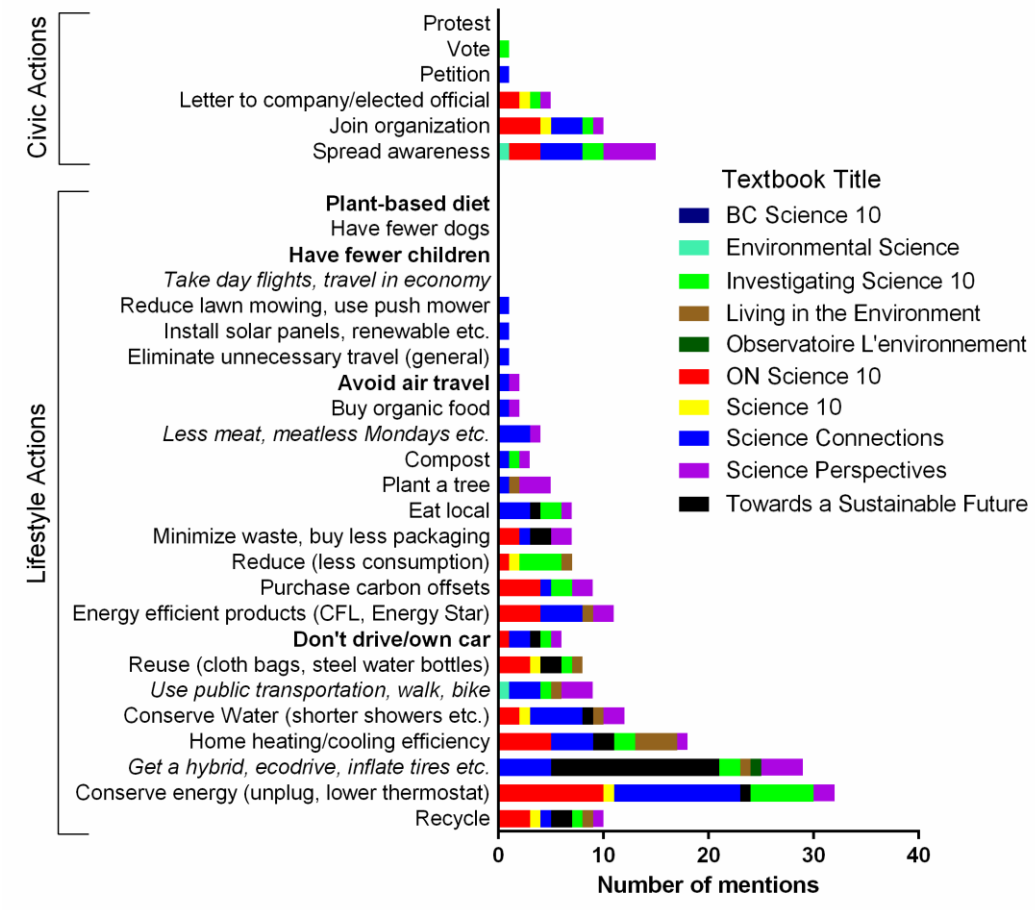

Figure 3: An analysis of actions recommended for mitigating climate change in ten Canadian high school science textbooks. For both lifestyle and civic actions, recommended actions are ranked from broadest coverage at the bottom (most separate textbooks suggesting the action) to least coverage at the top. High-impact actions are bolded, and italics indicate a behaviour that partially meets the requirements of a high impact action (e.g. "drive less" instead of "don't own a car").

The action recommended in the most textbooks was recycling, followed by energy conservation measures such as, “Switch off lights and unplug appliances” (Adam-Carr et al., 2010). Of the civic actions, spreading awareness was the most commonly recommended, while there were no suggestions in any textbook to attend a protest or demonstration.

4 Discussion

4.1 Curriculum Analysis

4.1.1 Research Question 1: Curricula comparison between Canada and the United States

Canadian provinces appear to offer a more rigorous treatment of climate change than their American counterparts. Using the framework of Golden and Francis (2014), there was a higher proportion of Canadian provinces (70%) that scored a ‘4’ than American states (10%) (Figure 4).

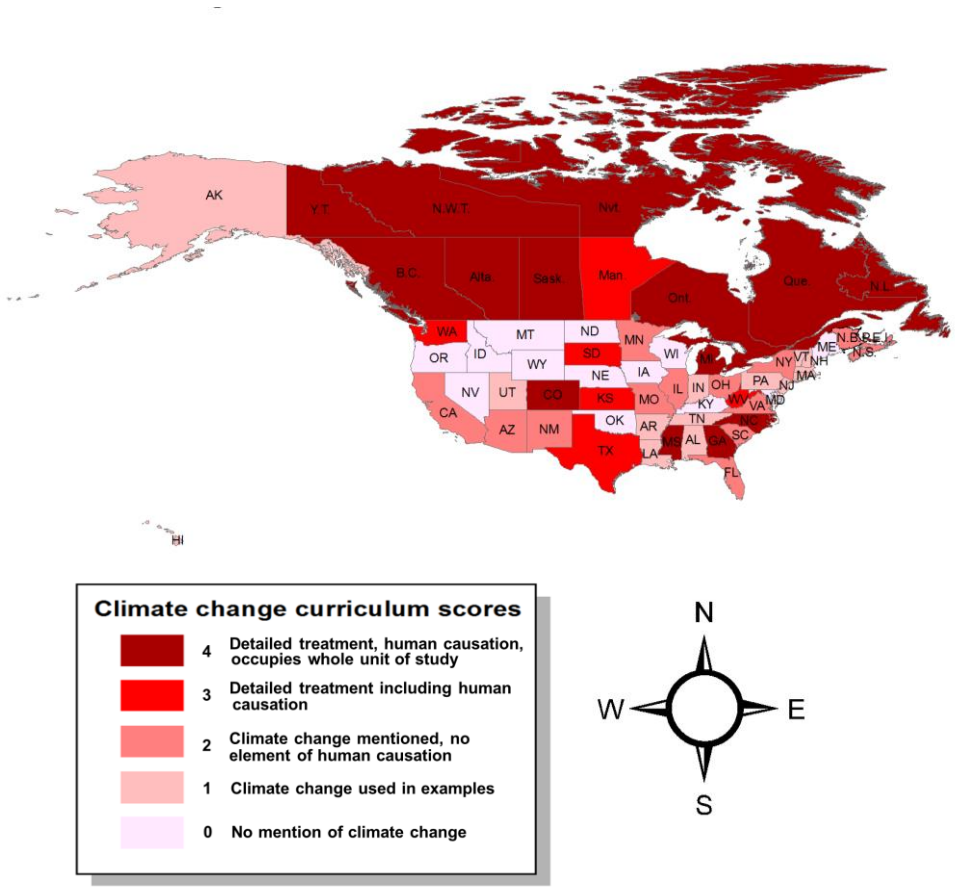

Figure 4: A map of Canada and the United States, showing coverage of climate change in science curricula documents, scored according to framework from Golden and Francis (2014). 70% of Canadian provinces were assigned a score of 4, compared to 10% of American states.

Despite the comparatively lower scores in American states, the Next Generation Science Standards (NGSS), which are a set of curriculum documents aimed to improve science education in the United States (Achieve, 2015), scored a '4' in this framework and are in use by some states as well (Golden and Francis, 2014). Still, issues remain with these standards, including which states will choose to adopt them and how they will do so. For instance, there was considerable controversy when West Virginia (temporarily) altered the climate portion of the NGSS standards to cast doubt on the scientific understanding of climate change (Schwartz, 2014). So while improvements may be forthcoming in climate change education for the United States, they remain uncertain.

4.1.2 Research Question 2: Provincial coverage of climate change

The curriculum analysis for climate change revealed that Ontario and Saskatchewan provided the most comprehensive education on the topic. Both covered five of the six core teaching topics (Nicholas et al., 2014) in mandatory courses, as well as scoring the highest possible mark according to the first framework employed (Golden and Francis, 2014). Saskatchewan additionally covered all six topics in an optional environmental science course. A detailed categorization table is available in Appendix C.

Manitoba, while still covering three of the six categories and scoring better than many American states (Golden and Francis, 2014), displayed a tendency to depart from the scientific consensus. For instance, specific learning objectives moderated the idea of anthropogenic climate change, saying that the climate "can be influenced" by humans (Manitoba Education, 2001) rather than describing humans as the major driver of climate change. But divergence from scientific understanding was much more pronounced in supplementary materials in the curriculum, which recommended reading material produced by "Friends of Science", an organization described as opposing the IPCC understanding of climate change (Manitoba Education, 2006). The curriculum document adds, "It should be noted that there is significantly polarized debate on the issue among scientists. Students should be justifiably cautious about accepting unsubstantiated claims about global warming" (Manitoba Education, 2006). This is particularly concerning given that there actually is no "significant, polarized debate" in the scientific community (Cook et al., 2013). Furthermore, individuals who hold the misconception that there is widespread disagreement amongst scientists on this issue are less likely to support policies to mitigate climate change (Ding et al., 2011).

Box 3: Statements in curriculum documents that oppose a scientific consensus on ACC	
Manitoba	It is important for students to conduct research that is fair and representative of alternative, and viable, scientific viewpoints on such a vital issue. Students should research climate science, as articulated by organizations such as The Friends of Science—Providing Insight into Climate Science (see <http://www.friendsofscience.org/>). This large, international community of climate scientists, for instance, holds views quite contrary to what has been supported by Environment Canada and the United Nations' (UN) Intergovernmental Panel on Climate Change (IPCC) over the past decade … Students could role-play disparate points of view within the climate science community. (Manitoba Education, 2006) A discussion of the merits and shortcomings of the scientific community's research agenda into the anthropogenic CO2 contribution to potential global warming could be conducted in relation to this topic. It should be noted that there is significantly polarized debate on the issue among scientists. Students should be justifiably cautious about accepting unsubstantiated claims about global warming. This issue provides an opportunity to engage students in the patterns of behaviour that occur within science during what can be termed a "crisis" situation. (Manitoba Education, 2006)
Newfoundland and Labrador	Teachers should ensure that students understand that there are contradictory viewpoints to this issue. Students may have seen Al Gore's movie "An Inconvenient Trust [*sic*]" which explains the anthropogenic side of the story. Teachers should ensure that students know that there may be a natural cyclic event on Earth causing global warming. Some sources include volcanic activity, ocean currents, solar variability, Earth's orbit and tilt, plate tectonics and biological evolution. (DEECD, 2010) Not all scientists agree on the science surrounding climate change. Some scientists are skeptical and believe that climate change is a natural, cyclic process. Research and try to find opposing arguments to climate change. Take one side of the issue and debate it with another student with an opposing viewpoint. (DEECD, 2010)
Prince Edward Island	Not all scientists agree on the science surrounding climate change. Some scientists are skeptical and believe that climate change is a natural, cyclic process. Research to find opposing arguments to climate change. Take one side of the issue and debate it with another student with an opposing viewpoint. (DEECD, 2011)

Manitoba was not the only province with curriculum documents conveying disagreement amongst the scientific community (Box 3). The supporting documentation for both Newfoundland and Prince Edward Island undermine the notion of a scientific consensus, suggesting that debate should be encouraged amongst students on climate change. This raises the question of how climate change is best taught, and whether debate should at all be encouraged on the issue, as it may lead students to incorrectly conclude that there remains scientific disagreement on the topic.

During the textbook analysis for research question 5, I also came across numerous statements that encouraged debate or controversy on subjects that the vast majority of scientists would agree upon (Box 4).

Box 4: Statements encouraging debate or controversy on climate change in Canadian science textbooks

ON Science 10

Human activities, such as the burning of fossil fuels, releases [*sic*] carbon dioxide into the atmosphere, which may result in climate change. (Dickinson et al., 2009)

Scientists are still debating whether climate change is affected more by slow, gradual changes or by sudden, catastrophic changes. This question is at the centre of the controversy about whether humans can cause Earth's climate to change significantly. (Dickinson et al., 2009)

"Scientists Disagree Over Global Warming." "Future Climate Uncertain." You may have seen headlines like these on web sites or in newspapers or magazines, or heard similar claims in the media. Both statements are true. However, non-scientists and scientists often interpret disagreements and uncertainties in different ways. (Dickinson et al., 2009)

Not all scientists, governments, politicians or individuals agree on how scientific data should be interpreted. (Dickinson et al., 2009)

Investigating Science 10

Positive Effects of Climate Change
Not all the projected effects of climate change are negative. Ontario is a major farming province, with over 82 000 farmers and 5.5 million hectares under cultivation … As climate change brings warmer temperatures, the length of the growing season will increase, and farmers will be able to increase crop yields and grow crops that require more heat.
As the sea ice on the Arctic Ocean melts, the Northwest Passage shipping route will be open water every summer. Sailing through the Arctic islands will substantially shorten the shipping distance from Europe to China and Japan, reducing the cost of transporting goods. Cruise ships can sail farther north than before, so tourists can follow in the wake of Arctic explorers such as Henry Hudson and John Franklin. (Sandner et al., 2009)

However, some people argue that today's global warming could just be part of a natural climate cycle that occurs over thousands of years. They believe that until such cycles are fully described, the human contribution to global warming remains debatable…
Climate skeptics, on the other hand, make three main points.

- We do not understand Earth's climate well enough to make predictions about the future.
- The global climate is getting warmer but not because of human activities.
- The global climate is getting warmer, but this will create greater benefits than costs.
  (Sandner et al., 2009)

Science Perspectives 10

Most discussions of climate change give the impression that the impacts of climate change will always be negative. However, there may also be some positive impacts. (Adam-Carr et al., 2010)

Possible benefits of Climate Change in the Arctic … Less sea ice means that it will become easier for ships to reach the Arctic and the valuable resources there. In addition, ships could follow much shorter routes by travelling across the Arctic through the Northwest Passage rather than taking longer, more southern routes. (Adam-Carr et al., 2010)

In these examples, doubt is cast on the consensus position that humans are driving climate change as well as on the scientific consensus itself. Literature on the subject of climate change skepticism tends to identify three main typologies: (1) trend skepticism, which denies that the earth is warming, (2) attribution skepticism, which denies that warming is caused by humans and (3) impact skepticism,

which accepts 1 and 2, but questions how harmful or soon the effects of climate change will be, and therefore questions the need for action (Painter and Gavin, 2015; Poortinga et al., 2011). Rahmstorf, who first defined these three categories, labels the highlighting of benefits, such as extending agriculture into higher latitudes, as an argument of impact skeptics (2004).

The "benefits" purported in the textbooks are also contested. While some models indeed predict that a longer growing season in Ontario will result in increased crop yield (Cabas et al., 2010), other studies remind us that higher temperatures will also result in increased plant diseases in agriculture (Boland et al., 2004) and more extreme weather events (Motha and Baier, 2005), both of which have negative consequences for farmers. Even more suspect is the assertion that the opening of the Northwest Passage is beneficial because it will lead to increased shipping and tourism (Sandner et al., 2009). On the topic of increased shipping in the area, the Arctic Marine Shipping Assessment cited numerous concerns, including the risk of increased oil spills, more ship strikes on marine mammals, disruption of animal migration routes, introduction of alien species and increased black carbon emissions that would accelerate the melting ice (Arctic Council, 2009).

Regardless of the existence of minor benefits of climate change, the question remains whether they need to be taught. Given the overwhelmingly negative consequences outlined by the IPCC (2014b), it is doubtful whether students need to receive a "balanced" view in this regard. Some researchers do suggest that scientists should present data "that seems to undercut the scientific consensus," in order to protect "the scientist from communication strategies that elicit doubts about scientific competence or integrity" (Jamieson and Hardy, 2014). Applying that thinking to this context, a skeptical student might trust a textbook more if it presents some data that contradicts the consensus view. I suggest that until this topic has been studied further we remain unsure of the best answer to this question.

While some provinces (and textbooks) suggest teaching climate change as a debate, few are teaching the scientific consensus of climate change. Only one province (Saskatchewan) covered the core teaching topic "We're sure", and only in a non-mandatory course (Table 3). The "We can fix it" topic was also sparsely covered, with only five provinces addressing this concept in their objectives. But the way in which "We can fix it" is covered is also an area of interest. For instance, some provincial curricula suggest individual actions that would lead to climate change mitigation (MEDU, 2008a) while others discuss the political steps that can be taken (DEECD, 2010). But no province connects these two things – i.e. how can an individual contribute to political or structural changes. Some textbooks fill these gaps, discussing both the meaning (DiGiuseppe et al., 2011) and existence of scientific consensus (Adam-Carr et al., 2010), as well as prompting students to participate in political

processes: “Make a list of five ways you can reduce your personal impact on climate change and three ways you can influence corporate and/or governmental action of climate change” (Sandner et al., 2009). So even with little prompting from the curriculum, textbooks contain sections politicizing climate change and offering explanations on the meaning of scientific consensus.

An understanding of scientific consensus as a concept would benefit students, and not just for climate change education. Kahan et al. (2011) found that both conservatives and liberals showed poor understanding of scientific consensus, mostly taking it to mean whatever view supported their own ideological preference. This is important for any issue where scientific understanding may differ from public opinion, as is the case with the anti-vaccination movement, which has caused a resurgence of easily preventable diseases in developed countries (Gumbel, 2015). It is possible that some of these issues could be avoided with more education on the matter.

4.1.3 Limitations and restrictions in the curriculum analysis

This analysis may not provide a complete picture on climate change education in secondary schools in Canada. It is possible for some provinces that climate change was given a more detailed treatment in a different course, for instance in a geography, or social science course, or prior to the secondary level. Only secondary science courses were examined. Furthermore, only curriculum documents that were available on government websites were examined, which would exclude locally developed courses (courses which are created for a small area or even a single school). International Baccalaureate courses, which are offered at 156 secondary schools in Canada (International Baccalaureate, 2015), and Advanced Placement courses, which are taken by less than 1% of secondary students (The College Board, 2015), were also not considered. Finally, it should be noted when comparing the different curricula that a province which covers more core teaching topics is not necessarily giving a more thorough treatment than a province covering fewer topics. For instance, British Columbia covers three topics, but does so in a mandatory course, while Alberta covers four topics, but in a course that not every student will take.

There are also numerous ways of presenting climate change (or environmental education) in the curricula. Some provinces might attempt to mainstream or infuse such a topic throughout many different courses and grade levels, while others might design one course with a significant environmental component to cover all desired learning objectives. It is also possible that teachers spend more time on environmental issues in other subjects, or use climate change as an example in other aspects of the science curriculum. But there is some evidence that mainstreaming climate change produces inferior results. When the Ontario government eliminated the environmental

science course, intending for ecological concepts to be taught throughout the curriculum, teachers tended to neglect environmental science in favour of the core curriculum (Puk and Behm, 2003). Another, more recent study consisting of interviews with 11 educators teaching climate change in Alberta found that teachers were already wary of the subject of climate change, partially due to its inherently interdisciplinary nature and the perception of it being a fringe subject in the curriculum (Chambers, 2008). Insisting that environmental issues should be spread throughout many courses would arguably force it into an even more interdisciplinary mold and remove the credibility that it gains by being part of the explicit curriculum. Conversely, if teachers receive proper training and feel comfortable integrating these topics, it might prove to be a more effective method. One curriculum development interviewee, for instance, saw the integration of sustainability concepts throughout different grades and courses as a strong, positive characteristic of their province's education system.

4.1.3. Research Question 3: Curriculum development in the different provinces

Several curriculum contributors very firmly denied feeling any direct political pressure while writing the curriculum. This agrees with my curriculum analysis, which shows no obvious relationship between a province's politics and their approach to climate change. British Columbia, which was the first province to institute a carbon tax (Duff, 2008) and the only province where a Member of Parliament from the Green Party has been elected (Hunter, 2011) has a similar score in the Nicholas et al. (2014) framework as Alberta, which, until recently, had the same, conservative political party for over forty years (Gerson, 2012). Additionally, the figure in Appendix D shows the lack of relationship between a province's propensity towards political environmentalism (measured by percent of vote taken by the Green Party of Canada) and its coverage of climate change in secondary science curricula. It is somewhat reassuring then that curriculum development seems to be occurring without the direct interference of external, ideological pressures.

Some curriculum developers noted a conflict between keeping content to a manageable level in courses and including a variety of topics. If climate change is to receive more coverage, especially in provinces which did not address it fully, then curriculum writers would need to be convinced that it truly merits special treatment. But overall, the curriculum development process seems to function well, includes numerous checks and balances, and relies on expert opinion from a variety of sources. Combined with the tendency to follow other provinces that are showing leadership on subjects like climate change, I would suggest that this aspect of climate change education will continue to improve as curricula undergo their regular updates and revisions.

4.2 Moving towards an evidence-based education on climate change

One hypothesis that has been considered for the small risk perception associated with climate change is a lack of scientific literacy (Kahan, 2013). Taken further, this hypothesis suggests that in order to solve the issue of apathy towards climate change we only need more science education. However, Kahan et al. (2012) found that scientific literacy does not correlate with concern for climate change, but simply correlates with high polarization on the issue. To avoid basing policies on unsupported theories, Kahan (2013) proposes that climate change communication should not be based on theories unless they are empirically supported. In a similar way, I propose that the design of climate change education should be evidence-based. This means propagating ideas and knowledge that are grounded in science and using educational methods that are supported by empirical findings.

So, is Canadian education already following an evidence-based model on the subject of climate change? As an example, in my review of climate change education, I listed six core teaching topics related to climate change, five of which were associated with support for mitigation policies. The remaining topic (It's climate) simply describes those learning objectives associated with climate in general, such as ocean currents, or the greenhouse effect. This topic was the most commonly addressed amongst different provinces, with every province and territory covering the subject, and most in a mandatory course. If scientific literacy did lead to concern about climate change, then this focus on climate knowledge would be merited. However, studies have shown that knowledge about the environment does not lead to action for the environment (Kollmuss and Agyeman, 2002) nor for climate change mitigation (Kahan et al., 2012). Yet we see that many provinces neglect to choose standards that would actually lead to increased concern or action for climate change in their student populations, instead focusing solely on knowledge.

In terms of how the curriculum is delivered, and even the practices of those who design the curriculum, Canadian education sometimes tends towards balance rather than evidence (Box 2). Being able to weigh the scientific merit of an argument is certainly a useful skill within scientific literacy, but should students be evaluating issues where a scientific consensus already exists? Some members of society may see climate change as bad while others consider it beneficial, but the scientific evidence overwhelmingly points to negative outcomes both for humanity and the biosphere (IPCC, 2014b). With global temperatures threatening to cause extinction for one in six species (Urban, 2015) and 250 000 human deaths per year predicted in coming decades due to climate change (WHO, 2014), an evidence-based approach would not be moderated on this matter.

The desire of curriculum developers to take a balanced, neutral approach to climate change is admirable so long as that balance falls within the boundaries of scientific agreement. But the results of this study show that this is not always the case.

4.2.2 Research Question 4: High-impact actions

The high level of agreement (95%) amongst the expert group who attempted to distinguish high-impact actions for reducing an individual's carbon footprint from low-impact actions shows that those who are very well versed on the matter already have good understanding on this topic. In the literature there seems to be a growing awareness that air travel, meat consumption and the use of personal vehicles are among the most harmful actions for the climate (though less emphasis seems to be placed on fertility decisions). This can be seen in surveys measuring environmental behaviour (Armel et al., 2011), and critiques of the behaviour of scientists and academics (Le Quéré et al., 2015). But I was unable to find articles that quantitatively compared some of these high-impact actions, and the textbook analysis showed a lack of focus on such behaviours. All of this suggests that education could benefit from a better focus on the most important behaviours in regard to climate change mitigation.

The high-impact actions that I propose allow less room for a direct rebound effect; someone who foregoes owning a vehicle would have a difficult time increasing their emissions by riding public transit too much, compared to buying a hybrid electric vehicle but driving it excessively. Indeed, conservation has been found to be more effective than efficiency improvements in terms of the rebound effect (Murray, 2013). Similarly, the high-impact actions are more user-friendly for reducing carbon emissions. Taking the example of GHG emissions associated with food production, while some studies have problematized the idea of increased organic food (van Huylenbroek et al., 2009) or local food (Coley et al., 2009; Edwards-Jones, 2010) as mitigation strategies, the efficacy of decreased meat consumption is much less contested (Foley et al., 2011; Popp et al., 2010; Stehfest et al., 2009). Someone who has seen a long list of options for a more climate-friendly lifestyle might try to increase their organic food intake and then simultaneously undo their own efforts by driving 7km round-trip for their vegetables (Coley et al., 2009). But an individual who has learned just four key actions is less likely to make such a mistake.

None of the high-impact actions overlapped with those identified for households by Gardner and Stern (2008b). The single action which they identified as being of the highest impact was to buy a more fuel efficient vehicle. In another paper, which used a similar improvement in fuel efficiency as is seen in the Gardner and Stern paper (2008b), this action was estimated to reduce carbon emissions

by 1.85 tonnes per year (Murtaugh and Schlax, 2009) while my own estimates from current Natural Resources Canada data suggested a reduction of 1.47 tonnes per year for an individual or 0.95 tonnes per year when factoring in the average number of vehicle occupants. As already noted, this action is subject to concerns with whether the efficiency of purchasing a new car is outweighed by manufacturing considerations (see also Zolnik (2012)). The other significant actions (such as install/upgrade attic ventilation/insulation) are of lower impact, are subject to decreasing gains as electrical grids decrease in GHG intensity (Chitnis et al., 2013), and will often become inevitable as governments mandate efficiency improvements (EPA, 2006; European Commission, 2009; NRC, 2014).

Despite not being included in my short list, Gardner and Stern demonstrated that household heating and efficiency changes can make a significant impact on a household's carbon impact (2008b), and indeed these were the most frequently recommended behaviours in my textbook analysis. However, household and automobile efficiency improvements consist of many small and distinct behaviours that are less easy to transmit to students in the form of a short list, which is another reason why they remain excluded from my suggested high-impact actions. These small behaviours and even compromises (such as switching to a more fuel efficient vehicle) are admittedly useful for spurring change in an adult who has already invested in a certain lifestyle and cannot easily make major changes. But as my audience consists of youth who have mostly not purchased cars, chosen where to live and so forth, it is possible to make more demanding suggestions, such as not purchasing a personal vehicle at all. One Ontario textbook says, "making a difference doesn't have to be difficult" and provides the example of switching from plastic bags to reusable shopping bags in order to save 5kg of CO_2 per year (Dickinson et al., 2009). Instead of emphasizing the ease of climate mitigation through nearly insignificant personal actions, I propose giving students challenging but meaningful actions to consider. This is all the more important because the challenge is delivered during a time frame when decisions can shape the next fifty years of an individual's life.

4.2.3 Is there widespread scientific support for the high-impact actions?

It is possible that certain actions might be environmentally beneficial in one area but could be questionable in another, or that some experts would consider a behavioural change to be paramount, while others might see it as peripheral. In the selection of my actions I looked for behaviours that would be considered positive by a wide number of experts, and would be applicable to many people in varying locations. The range of potential climatic impacts of my recommended

actions, as found in a variety of studies based on locations in the developed world, can be seen in Figure 2.

High-impact Action: Have fewer children

While I have included only one study on the carbon footprint of having a child, it is perhaps the one action whose impact should be self-evident. There may be disagreement of how or whether the emissions of a child should be allocated to a parent, but it is clear that the act of adding another human to the planet will have quantifiable consequences for the environment (Hall et al., 1994). The theory behind this is simple. If we look at Waggoner and Ausubel's revised IPAT identity (ImPACT), environmental impact (I) can be influenced by population (P), affluence (A), consumption (C) and technology (T) (2002). My other high-impact actions aim to lower consumption in order to reduce environmental impacts. But decreasing population will have the same downward forcing as decreasing consumption. In a more concrete (although ethically questionable) example, a Chinese Foreign Ministry official noted that his country's one-child policy averted 1.3 billion tonnes of CO_2 in 2005 alone (Doyle, 2007). A conscientious individual seeking to be environmentally friendly should be aware of the cost of their reproductive choices, and climate change communicators would be remiss for failing to pass on this knowledge.

Developed nations are showing that they are not averse to influencing fertility decisions, though not in a sustainable manner. A clever marketing campaign was conducted in Denmark encouraging couples to become parents (Moss, 2014), while Australia, South Korea and Russia have all promoted or incentivized childbirth in the last decade (BBC, 2006, 2014; Press, 2007). So there are already several precedents in developed nations for the government to influence the reproductive decision-making of the population, but in the wrong direction.

This is by far the most significant of all the actions I identified, as can be seen in Figure 2. Data was taken from a study that looked at the carbon legacy of a single birth, in a developed nation (Murtaugh and Schlax, 2009). It therefore includes the effect of not only one child, but the children that the child will likely go on to have as well. The range of values reflects three scenarios of differing future emissions levels which are up to two orders of magnitude larger than other high-impact actions.

High-impact Action: Live car free

MacLean and Lave (2003) note that one option for dealing with the issues of cars would be their outright elimination, which would reduce or eliminate annual highway deaths, urban congestion,

smog and land occupied by roads and parking spaces. While this is an unlikely goal, it can still be worthwhile to significantly decrease the number of cars on the road, thereby reducing a long list of externalities. Some of these externalities can be ameliorated without behavioural change through new technologies such as battery electric vehicles (BEVs). Yet BEVs still produce high carbon emissions (Figure 2) and present lingering concerns. Presently, internal combustion vehicles can actually produce less emissions than BEVs that are charged in areas with coal power (Hawkins et al., 2012). Even if widespread adoption of renewables increases enough to cover the added load of BEVs, these vehicles still have higher toxicity impacts than internal combustion vehicles through their use of rare earth metals etc. (Nordelöf et al., 2014) that should give us pause before accepting them unconditionally. Since the most advanced and seemingly most green technologies are so problematic in this area, it seems that there is little chance technological progress will remedy this unsustainable action in the near future.

High-impact Action: Eat a plant-based diet

I quantified the potential impacts of one person changing from an omnivorous to a plant-based diet, and showed that on a per-capita basis this is a relatively important action (Figure 2). But while some people are in a position of choosing whether to fly or own a car, everyone must eat, making the repercussions of this decision even more important on a global scale. We know that global food demand is increasing rapidly, with potentially severe consequences for the environment (Tilman et al., 2011). But we also know that a shift in diet could be of huge potential importance in relieving this burden. Cassidy et al. (2013) estimate that if food were grown only for human consumption, instead of for biofuels or feeding livestock, we could accommodate the caloric needs of an additional 4 billion people. And while technological improvements in agriculture may ease emissions growth, research has shown that a diet shift is actually a more effective way to mitigate climate change (Popp et al., 2010). Because of the unlikelihood of technological solutions, researchers have in fact concluded that "dietary changes are crucial for meeting the 2°C target with high probability" (Hedenus et al., 2014).

Omnivorous diets not only produce more carbon, but also use more phosphorus, more primary energy (Meier and Christen, 2012) and more land (Stehfest et al., 2009), thus contributing to deforestation and biodiversity loss. It is not surprising that those urging a change in diet, describe it as a

> …step that can be easily taken and will have a positive effect more quickly than other possible options. For this reason, drastically reducing the consumption of animal-based foods has to be a

> necessary first step in any environmental movement to preserve the planetary resources for the coming generations. (Saxena, 2011)

I therefore posit that this is an important action both in terms of climate change and social justice, which necessitates a widespread change in behaviour which could be accomplished through government incentives and education (McMichael et al., 2007).

High-impact Action: Avoid air travel

Depending on flight distance or the class of seat chosen by an individual, air travel can considerably expand a person's carbon footprint. On a global scale, aviation accounts for nearly 5% of total anthropogenic radiative forcing (Lee et al., 2010) and aircraft emissions are expected to continue rising in the future (Sgouridis et al., 2011). Despite this issue, "substantive reductions in aviation fuel usage are possible only with the introduction of radical technologies" (Lee et al., 2009). One such technology is hydrogen fuels. Unfortunately hydrogen is likely to be adopted for air travel only if society makes a general shift to a hydrogen-based fuel economy, and this itself would only be beneficial if the hydrogen was produced with renewable energy (Lee et al., 2009).

Biofuels offer another potential option, however they come with drawbacks; improper harvesting of biofuels can have overwhelmingly negative consequences for the climate (Fargione et al., 2008) as well as for biodiversity and food security in developing nations (Searchinger et al., 2008). Proper use, conversely, restricts the overall quantity that can be used by limiting sources to a handful of options (Tilman et al., 2009). Though biofuels represent the solution that is closest to possible implementation (Kivits et al., 2010) any new technology faces hurdles in an industry that is risk averse and hampered by slow aircraft turnover (Bows et al., 2009). The Swedish Environmental Protection Agency confirms this: "Unlikely technical development is required to attain really low emission levels from aviation in the long term. The aircraft being built today will be flying in 2020 and perhaps even in 2050" (Agency, 2010).

Based on all of these drawbacks, it is understandable that the IPCC suggests diverting tourists from aviation to high speed rail (Sims et al., 2014) while other researchers have similarly called for a downward shift in travel demand, either by government regulation or voluntary personal action (Sgouridis et al., 2011). Given the unlikelihood that the industry will soon decouple from carbon on its own, and the high per capita footprint of aviation, I suggest this as the fourth high-impact action.

To summarize, technological progress in the coming decades may reduce the environmental impact of personal vehicles and aviation, but not enough to forego changes in personal behaviour. In

describing the need for improvements in global transportation, Working Group III of the IPCC says, "transition of the sector may also require strong education policies that help to create behavioural change and social acceptance" (Sims et al., 2014). Thus in the areas of agriculture, aviation and personal vehicles, I suggest the need for personal changes to accompany technological progress.

Potential High-impact Action: Don't own a pet dog

One potential for a high-impact action is pet ownership, specifically dogs. Americans own 83 million dogs (Society, 2014) while Canadians own 6.4 million (CAHI, 2015), which represents 26% and 18% of the population respectively. While some researchers have suggested that animal protein given to pets may be more wisely allocated to humans (Boland et al., 2013), there remains little peer-reviewed literature on the subject. In Figure 2, dog ownership can be seen as an action with an extremely large range of possible emissions, partially due to the considerable differences in the size of dog breeds, but also due to the variability between the two LCA studies that quantified the emissions associated with dog food products. One found emissions of 23.14kg CO_2e/kg dog food (Rushforth and Moreau, 2013) while another found a value of 0.9kg CO_2e/kg dog food (Eady et al., 2011). This could be accounted for in different ways; the studies examined two different brands of dog food, containing different percentages of meat, produced on different continents. Regardless, this huge variability does not lend confidence to including this potentially high-impact action in a list of other, very well established recommendations. It is hoped that more research in the future, including an examination of the full impact of dog ownership, taking into account such things as the carbon footprint of trips to the vets, medications and rebound effects would reveal whether this is an action worth focusing on.

Uncertainty regarding the magnitude of high-impact actions

It should be noted that all of the identified actions have some potential to be slightly less effective than suggested by Figure 2, based on how they are replaced and on rebound effects. For instance, not travelling by air could result in a long train ride or having one fewer child could result in a couple spending more on material goods (indirect rebound effect). However, someone travelling by air might also choose to replace their travel by holding a teleconference instead of taking a train, and someone choosing not to own a car might replace their transportation needs by walking or biking instead of taking a bus, leaving only indirect rebound effects to be accounted for. Given the paucity of research on some of the high-impact actions (having one fewer child), the previously mentioned reductions were not accounted for in my calculations.

One study in Sweden found that the rebound effects of adopting a low-carbon diet could outweigh the original benefits (Alfredsson, 2004). Though another study did not reproduce this back-fire effect in Australia (Lenzen and Dey, 2002), even if the rebound effect was widespread it would still not prove that we should abandon the ideal of a plant-based diet. We have already seen that a plant-based diet is necessary for a sustainable future. Instead, such a result would simply mean that we must reduce the rebound effect for this action.

4.2.4 Research Question 5: High-impact actions in science textbooks

Now that the high-impact actions have been identified, it is worth discussing whether or not we are already communicating these actions to students. While I did not have the opportunity to ask teachers how and what they communicate, the content of textbooks can be a good proxy. Certainly textbooks are used by teachers, both to inform their own teaching and as learning material that is provided directly to students. An analysis of relevant portions in ten textbooks that directly address climate change in Canada showed that these high-impact actions are not being communicated frequently or effectively to students.

Two high-impact actions (having fewer children, and not owning a pet dog) were not mentioned at all in any textbook, while the remaining three actions were often mentioned in a way that reduced their effectiveness, for instance, by suggesting "driving fuel-efficient vehicles" (Sandner et al., 2009), instead of not driving at all. So despite the fact that avoiding air travel can be up to 15 times more effective than recycling (based on a long-haul flight) it was mentioned one-fifth as frequently. Some opportunities to introduce positive behaviours were also missed or dampened. For instance, in a section discussing the effects on the climate of methane produced by ruminants, one textbook states,

> Scientists have suggested some unique ways to capture, or sequester, carbon from methane. One suggestion involves having cattle wear backpacks to capture the methane released from their digestive track, as you saw at the beginning of this chapter. This methane could be collected for use as a fuel. Other scientists suggest that simply feeding cattle clover and alfalfa rather than corn and grain will reduce methane emissions by those animals by 25 percent. Some environmental activists have proposed a simple switch in human diets. (Dickinson et al., 2009)

Instead of linking this knowledge with practical advice to the reader about meat consumption habits, the textbook offers one way that scientists might solve the problem without adjustments to personal behaviour. It then says environmental activists propose a switch in human habits, when there are also scientists, who are regarded as a more trusted information source than environmental groups

(Leiserowitz et al., 2009) suggesting the same switch (Cassidy et al., 2013; Foley et al., 2011; McMichael et al., 2007). A student reading this section would walk away with little motivation to change their eating habits.

Given the lack of suggestions for political activity in the curriculum documents, textbooks provide a surprising range of statements encouraging civic participation. This is especially important considering the tendency for individuals to disbelieve in the effectiveness of political action in responding to climate change (Roser-Renouf et al., 2014) and the low voter turnout amongst youth in Canada's most recent election (Canada, 2014a).

The general lack of (effective) communication on the topic of personal action is perhaps understandable. Popular media coverage of climate change often misses opportunities to discuss mitigation and adaptation, for instance, by underreporting on the IPCC's Working Group III, which addresses questions such as restricting the consumption of red meat (Oneill et al., 2015). That being said, some textbooks did show progress in this regard. In a section instructing students to list actions for mitigating climate change, one text said, "At least one of your actions should be significant. For example, walking to school for a week reduces your carbon footprint much more than recycling a few pop cans" (DiGiuseppe et al., 2011).

In her investigation of environment clubs in Ontario, Lousley (1998) found that students, and even teachers, had a pre-occupation with low-impact actions, like recycling and littering: "Some students did not seem to be able to identify any other environmental issues". While the study is dated, it reminds us of the dangers of focusing our communications at a few, insubstantial targets just because they are uncontroversial. She goes on to say,

> Recycling was literally the extent of their familiarity with environmental activism … this trend may be sad but not surprising given the effort industry, municipal government, and the schools have put into promoting recycling and Earth Day. Indeed, members of all the clubs made frequent references to elementary school and home curbside recycling as key influences on their environmentalism. (Lousley, 1998)

In this instance, the message sunk in, but did not produce citizens who were engaged in effective environmental action.

I had a similar experience in my curriculum development interviews. Without being asked, two interviewees raised the subject of personal actions that students could take, and commented on the importance of such behaviours. One interviewee mentioned conserving water and composting, while the other mentioned gardening, local food, turning off lights and unplugging devices. Both

mentioned recycling. Teachers and curriculum developers are going to continue teaching students about positive individual actions, so they ought to be aware of which actions are the most effective at reducing an individual's carbon footprint.

4.2.5 A consideration of the carbon calculator

Another approach to helping individuals understand how to reduce their footprint is through carbon calculators (Lenzen and Murray, 2001), which is the approach taken in the Ontario curriculum (MEDU, 2008a) and therefore also in some Ontario textbooks. However, this approach in isolation is not ideal for several reasons. First, it is very likely that a students' carbon footprint will change significantly when they leave school and seek employment. As an example, a student who fills out a personal carbon calculator may not have had any flights in the past year, and therefore would not come to the realization that air travel is extremely carbon intensive if they only learned through a carbon calculator. In future years they might choose air travel over trains or buses without realizing the impact of their choices. Furthermore, most carbon calculators do not account for the effects of human reproductive choices, which can be considered a significant oversight. Carbon calculators also vary significantly in their results Padgett et al., (2008) which can also be seen by the aviation data displayed in Figure 2.

4.2.6 The need for high-impact actions

Canada opted to set its own CO_2 emissions targets for 2020, but already anticipates falling short of these targets (Environment Canada, 2014a). In fact, as Canada expects to miss this target by 116Mt in 2020 (Environment Canada, 2014a), it would take a reduction of 3.3 tonnes per person, based on 2014 population estimates (Statistics Canada, 2014b), to close the identified gap. These Canadian goals were part of a wider, international effort that, even if achieved, have been identified as insufficient to meet the safe climatic limit of two degrees of warming (den Elzen et al., 2011; UNEP, 2014). In a more rigorous attempt to maintain a reasonable likelihood of staying under this 2^{o}C limit agreed upon by the international community, Europe has established a 2 tonne per capita upper limit for the year 2050, which is equivalent to an 80-90% reduction in emissions compared to 1990 (European Commission, 2015).

A recent study suggested a more differentiated approach to national reductions, where countries would share a quota of CO_2 emissions based on a blend of population size and current emissions (Raupach et al., 2014). In this approach, in order to achieve a 66% chance of staying under the 2^{o}C limit, North America would need to cut its emissions by 7% per year (Raupach et al., 2014). Assuming

a steady population growth for Canada and given the unlikely assumption that Canada already began decreasing emissions by 7% in the year 2014, this would require that by 2030, Canadian emissions would be at 3.45 tonnes per capita. Seen in another way, each Canadian would need to decrease their own emissions by over 10 tonnes in the next 15 years (Appendix E).

The data from Raupach et al. (2014) does not factor in land use change, which is relevant to at least two of my high-impact actions (having fewer children and a plant-based diet). However it confirms that regardless of which pathway is used to reduce emissions, the reductions must be significant for developed nations if we are to stay beneath the $2^{o}C$ limit. I present these various CO_2 reduction targets (3.3 tonnes/person by 2020 for Canada's own target, and 10.9 tonnes/person by 2030 as an equitable way to avoid $2^{o}C$ of warming) not as mathematically precise figures that will inform a national strategy for personal emissions reductions, but as a way to see the scale of the reductions that are necessary. For instance, in Figure 5, I show some of my high-impact actions next to low impact actions that are often suggested in textbooks or the media. It is clear that even numerous and conscientious adoption of low impact actions would not close the gap between Canada's current emissions and its targets, let alone a target that is consistent with less than $2^{o}C$ of warming.

From the point of view of educators or communicators wanting to evaluate their own effectiveness, there is also a stark difference. For instance, in order to have the same effect in terms of carbon emissions, a climate change communicator could persuade one person to have one fewer child, or could persuade 684 teenagers who do not recycle, to recycle comprehensively for the rest of their lives[13]. Perhaps an even better way of understanding the problem is from the viewpoint of an individual trying to exist within a sustainable carbon budget. A European aiming to live beneath the sustainable limit of 2 tonnes per year would have a very difficult time doing so if 1.62 tonnes of their annual carbon budget was already used on a round trip transatlantic vacation.

[13] Based on 9441 tonnes of carbon for one additional childbirth, compared to the annual savings from recycling at 0.2125 tonnes, multiplied by the 65 years of life remaining for an average teenager. Data from Murtaugh, P.A., Schlax, M.G. (2009) Reproduction and the carbon legacies of individuals. Global Environmental Change 19, 14-20.

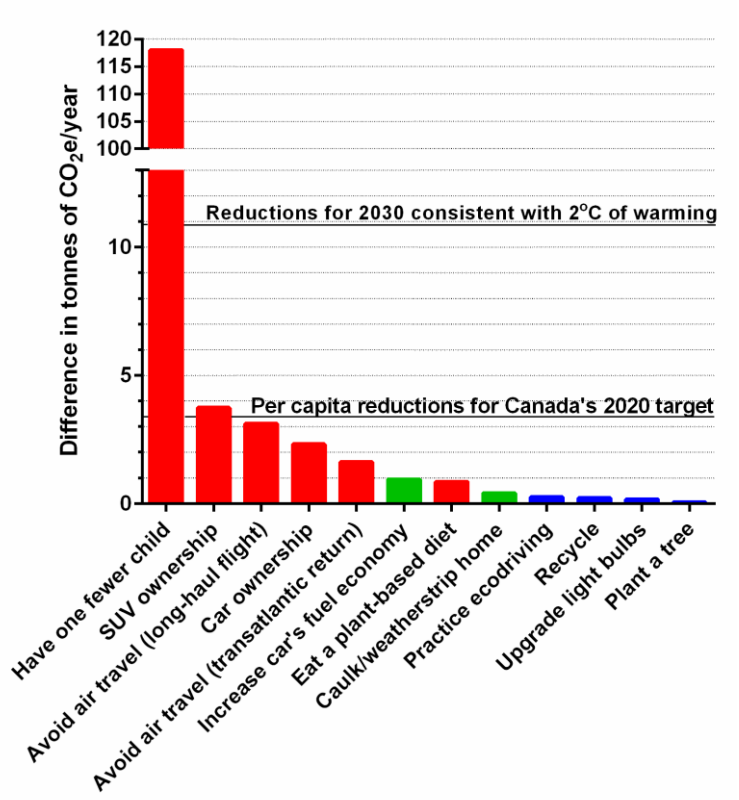

Figure 5: Examples of high-impact actions for climate change mitigation (red) with median value used for "Have one fewer child" and mean values from Figure 2 for remaining high impact actions. The long-haul flight is based on London to Hong Kong and the transatlantic flight is based on New York to London. Approximations of two suggestions in Gardner and Stern (2008b) are in green and selected suggestions from science textbooks are in blue. Solid lines indicate two reduction targets of note, translated into per capita emissions. Increased car fuel economy is based on an average change from a 20mpg 2014 SUV to a 31mpg compact car (NRC, 2015). Ecodriving value is from Barkenbus (2010). Upgrading lightbulbs represents a switch of ten incandescent light bulbs to CFLs, recycling is a mix of household products (Murtaugh and Schlax, 2009) and tree planting is from Freedman and Keith (1996). Rebound effects not included. See Appendix B: Calculations for details.

There is no doubt that governments have an important role to play in reaching reduction targets through regulation, and I do not suggest these measures as substitute for government action. Instead we can view them as something that governments should be encouraging, through mediums like education. The ability of governments to reach emissions targets without any changes in personal behaviour may actually be diminishing as time passes and inaction continues. For instance, as stringent reductions after the year 2010 appear less and less likely, remaining scenarios for limiting temperature increases rely on more rapid reduction at a later point (UNEP, 2014), often assuming the widespread use of unproven technologies such as bio-energy with carbon capture and storage (Fuss et al., 2014). There is therefore good reason to encourage reasonable societal changes in the near future rather than relying on technological advancements that may not come to fruition.

4.2.7 The controversy of high-impact actions

It should be acknowledged that some high-impact actions can introduce an element of controversy into the classroom. Decisions involving reproductive choices are obviously sensitive and will require educators to make use of the knowledge of the cultures and locations in which they are embedded. Even so, I would argue that it is better to provide teachers with this knowledge so they can choose how to best present it to their students, rather than discarding findings because they are too controversial.

While society may not be fully ready to endorse these ideas, it is important to remember the goals of education. To quote a statement from Alberta's *Inspiring Education* document, "We need to prepare kids for their future not our past" (Alberta Education, 2010). When we think about how climate change will alter our planet in the next thirty years, we know that students of today will experience a context that is very different from those that their parents and teachers enjoy at present.

4.2.8 Evidence-based communication of high-impact actions

Pro-environmental behaviour is associated with numerous variables, ranging from moral and social norms to guilt attribution (Bamberg and Möser, 2007), and yet knowledge of issues and action strategies is still a prerequisite to environmental behaviour (Hines et al., 1987). Canadian students cannot be expected to adopt pro-environmental behaviour if they do not have knowledge of the issue or action strategies on how to deal with it. Results from the textbook analysis show that students are possibly lacking this crucial first step. This is supported by studies of consumers' environmental knowledge, where many individuals underestimate the environmental effects of meat consumption while overestimating the effects of packaging (Lea and Worsley, 2008; Tobler et al., 2011). While understanding the consequences of certain actions may not be sufficient to prompt behavioural change, it is often necessary. It is for this reason that I compiled a short list of actions for students to take in order to reduce their carbon footprint. The next question becomes what is the best way to communicate this knowledge so that it results in pro-environmental behaviour?

To this end I have prepared resources which include: information sheets, a PowerPoint presentation, and teacher instructions for a cooperative learning lesson plan (Appendix F). Two variables associated with responsible environmental behaviour are knowledge of an issue and knowledge of action strategies (Hines et al., 1987), both of which are therefore included in the resources.

Other researchers have pointed out that environmental behaviour cannot take place if institutional barriers prevent them (Kollmuss and Agyeman, 2002). For this reason some simple political actions

are also suggested in order to provide a pathway for changing infrastructure etc. Additionally, studies of environmentally active citizens (Chawla, 1999) and individuals living a low-carbon lifestyle (Howell, 2013) both found social justice to be an important aspect of these lifestyle choices. I therefore attempted to link the high-impact actions with their effects on others and highlighted ideas of equity.

In order to address the important issue of students not feeling that their efforts can make a difference, known in the literature as locus of control (Bamberg and Möser, 2007; Hines et al., 1987), I explained the relationship between consumer choices and corporate response. Research has also shown that individuals are more likely to adopt an action, including recycling (Schultz, 1999), and reduced household electrical use (Schultz et al., 2007), if it is normalized, and the strategy has been recommended for climate change communication (Maibach et al., 2008). Based on this I have included a normalization strategy, for instance, reminding students that more and more young Canadians are choosing not to drive and to use public transit and live in walkable neighbourhoods instead (Eliot, 2014). In order to preclude vegetarian diets from being seen as an elite or alternative choice, I have adopted the nomenclature of "plant-based diet" (Beverland, 2014). Finally, as environmentally behaviour also has a significant self-interest component (Bamberg and Möser, 2007), I include numerous co-benefits of the high-impact actions. I attempted to focus on co-benefits that were more persuasive, for instance, choosing co-benefits of a vegetarian diet which were cited as being influential in personal decision-making on that subject such as health and ethical reasons (Fox and Ward, 2008; Tobler et al., 2011).

To convey these messages, fact sheets were created using a mix of text and graphics and aimed at a grade 10 audience, as that is the primary level at which climate change is taught in Canadian provinces. Teachers and students from Canada and Sweden assisted in providing feedback which guided the resource design, although ideally the resources should be quantitatively tested for their effectiveness at transforming behaviour. Other educational programs have already been evaluated for the efficacy in communicating understanding of climate change (Flora and Lappé, 2013) and for spurring behavioural change (Cornelius et al., 2014).

5 Conclusion

We have seen that in several regards Canadian climate change education is not consistent with scientific understanding. Doubts are cast on scientific agreement in curriculum documents and textbooks and debate is encouraged on issues that scientists have already settled. Curriculum documents often focus on knowledge about climate, missing opportunities to educate students with

outcomes that would motivate them to contribute to actual solutions. Still, some curricula and textbooks provide good models for how climate change can be communicated, and curriculum developers, unencumbered by political interference, will probably continue to improve on climate change education.

Given the numerous recommendations for personal behaviours to mitigate climate change that are seen in textbooks and sometimes in curriculum documents, educators would do well to focus on those behaviours that contribute the most to sustainable outcomes. For that reason, four high-impact actions were identified and compared to other actions that have been recommended in the past. Further research showed that the high-impact actions receive very little attention in textbooks, and are probably not frequently transmitted to students. In order to encourage teachers to educate students on these actions, I developed resources that utilize research in education, public health and behavioural psychology. More research is required to understand if such resources are effective, and how educators and communicators can more generally encourage the adoption of high-impact actions.

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7 Appendices

Appendix A: Interview material

Informed consent form

This study is investigating climate change education in Canada, part of which consists of secondary science curricula in the various provinces.

Results of the study will be reported as part of a graduate degree report/presentation and may be submitted to an academic journal. Participants can withdraw from the study at any time without giving a reason or facing adverse consequences. Participants are free to refuse to answer any of the questions. Participants may also withdraw their data within two weeks of the interview.

Participants are asked to:

> Participate in a digitally-recorded interview, anticipated to last one-half hour, in which you will be invited to talk about your experience in the curriculum design process, especially as it relates to the subject of climate change. Quotations reported in communications of this research will be sent to you to check for accuracy.

Recordings of the interview will be transcribed with pseudonyms. A separate pseudonym key will be created, and this pseudonym key as well as transcripts will be kept in password protected computer files. Recordings will be deleted once transcripts are finalized.

If you have any questions or concerns about the research please contact Seth Wynes at ess12cwy@student.lu.se, or Kimberly Nicholas at kimberly.nicholas.academic@gmail.com

Please initial <u>one</u> of the following:

☐ I consent to the placement of identifying information (my position and province, but not name) next to quotations of mine that have been approved by me for accuracy.

☐ I wish to remain anonymous (my position and province will not be provided alongside quotations).

I understand the procedures described above. My questions have been answered to my satisfaction and I agree to participate in this study.

_____ _____

Signature Date

Interview Guide

What was your official title while working on the science curriculum?

How many years of experience do you have in education?

What is the selection process for writers? (How are contributors to the curriculum chosen?)

Could you explain to me the overall process for writing the learning outcomes related to the climate change section in this course?

Were there any documents that were foundational to the curriculum writing process? (Example: "The Common Framework of Science Learning Outcomes K to 12")

How do you decide on the amount of space given to a topic?

(Example: Ontario has an entire unit devoted to climate change whereas New Brunswick only directly addresses it in an optional unit).

(Course name) was published in (date), so the writing process was taking place roughly (years) ago. Are you aware of any updates to the curriculum regarding climate change that you would like to see, given recent developments in science?

Politically, climate change is a very controversial topic. Did that influence the approach taken to writing parts of the curriculum relating to climate change? If so, how?

Appendix B: Calculations

Dog ownership calculations

To calculate the carbon footprint of a pet dog, three breeds of varying sizes were chosen. A Jack Russell Terrier to represent small breeds, a Labrador Retriever to represent mid-sized breeds and a St. Bernard to represent giant breeds.

Breed	Mean Mass (kg)	Source
Jack Russell Terrier	7	(Sutter et al., 2007)
Labrador Retriever	29.1	(Helmink et al., 2000)
St. Bernard	59	(Sutter et al., 2007)

I assumed that the largest portion of a dog's carbon footprint would come from their food, and that other contributors such as trips to the vet, toys, and vaccinations would be negligible.

To determine how much food these dogs would eat in a year I calculated their metabolizable energy (ME) requirements for a day. For the Jack Russell Terrier and the Labrador Retriever I used an equation calibrated for active dogs, $ME_{(kJ/day)} = 643(\text{Weight in kg})^{0.73}$, and for the St. Bernard I used the equation $ME_{(kJ/day)}=655(\text{Weight in kg})^{0.69}$ for less active dogs (Burger and Johnson, 1991). Jack Russell Terriers and Labrador Retrievers are classified by the American Kennel Club as high energy dogs, while St. Bernards are classified as low energy dogs, which is why they were assigned to the active and less active categories, respectively.

To determine the mass of food fed to each type of dog I assumed a dog food containing 14.97kJ/g (or 3577.92Kcal/kg), based on an in vivo study of ME in 24 dry dog foods (Laflamme, 2001).

Calculations for Food Mass

Jack Russell Terrier

$ME_{(kJ/day)} = 643(\text{Weight in kg})^{0.73}$

$= 643(7)^{0.73}$

$= 2661.54\text{kJ/day}$

$\frac{2661.54\text{kJ/day}}{14.97\text{kJ/g}} = 178\text{ g/day}$

Labrador Retriever

$ME_{(kJ/day)} = 643(\text{Weight in kg})^{0.73}$

$= 643(29.1)^{0.73}$

$= 7531.00\text{kJ/day}$

$\frac{7531.00\text{kJ/day}}{14.97\text{g}} = 503$ g/day

St. Bernard

$ME_{(kJ/day)} = 655(\text{Weight in kg})^{0.69}$

$= 655(59)^{0.69}$

$= 10917\text{kJ/day}$

$\frac{10917\text{kJ/day}}{14.97\text{kJ/g}} = 729$ g/day

Carbon Footprint Calculations

From a Life Cycle Assessment study of dry dog food (Rushforth and Moreau, 2013), I found that one kg of dog food results in a footprint of 23.14 CO_2 equivalents. Another study found 0.9kgCO_2e/kg food (Eady et al., 2011). Using this information we can calculate:

Jack Russell Terrier Footprint

23.14kg CO_2 eq/kg x 0.178kg/day x 365 days/year = 1503kg CO_2 eq /year

0.9kg CO_2 eq/kg x 0.178kg/day x 365 days/year = 58.5kg CO_2 eq /year

Labrador Retriever

23.14kg CO_2 eq/kg x 0.503kg/day x 365 days/year = 4248kg CO_2 eq /year

0.9 CO_2 eq/kg x 0.503kg/day x 365 days/year = 165.2kg CO_2 eq /year

St. Bernard

23.14kg CO_2 eq/kg x 0.729kg/day x 365 days/year = 6159kg CO_2 eq /year

0.9 CO_2 eq/kg x 0.729kg/day x 365 days/year = 239.5kg CO_2 eq /year

For interest's sake, the study by Eady et al. also found 390g of CO_2 eq/300g of daily food for a 4kg cat.

390g/day x 365days/year = 140 400g = 140.4kg CO_2 eq /year

Each of these values can then be divided by 2.63 persons per household in the United States (United States Census Bureau, 2015) which is similar to Canadian values of 2.5 persons per household (OECD, 2011), based on the assumption that dogs tend to be shared amongst households in a commensurate ratio.

Sources for Dog Ownership Calculations

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Additional Sources for Figure 2

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Calculations for Figure 5

Household Calculations

Much of the supporting information from Gardner and Stern (2008) was unavailable as the webpages are no longer accessible. However from the supporting information the figure of 10% reduction in overall home energy usage from weather-stripping a home was obtained (Gardner and Stern, 2008a). In the United States, each home produces approximately 10.92 tonnes of CO2 through energy use (EPA, 2014). A 10% reduction in energy use would result in savings of 1.092 tonnes per household. With 2.63 persons per household (United States Census Bureau, 2015) this would result in savings of 0.415 tonnes per person.

Other household calculations were also divided by 2.63 persons per household.

Ecodriving Calculations

The average US fuel economy is 24.9mpg, and US vehicles travel an average of 11 300 miles per year (Davis et al., 2014), which results in 453.8 gallons of gasoline being used per year. Ecodriving reduces fuel use by 10% at 2.31kg of CO_2/litre (Barkenbus, 2010), and with 3.78541litres/gallon, this would save 396.8kg of CO_2/year. Dividing by the number of occupants in the average car found in Davis et al. 2014 (1.55) we find 256kg of CO_2 saved per year.

Appendix C: Curriculum Analysis: Relevant learning objectives from Canadian secondary science curricula categorized according to Nicholas et al. (2014). Learning objectives from curriculum documents were downloaded from government websites, with sources listed in the final column.

Province	It's climate	It's warming	It's Us	We're sure	It's bad	We can fix it	Source
Alberta	**Science 10**		**Science 10**		**Science 10**		
Science 10 and Science 20 are mandatory for graduation for those aiming for a university program	Unit D: Energy Flow in Global Systems: Outcomes for STS/K 1. Describe how the relationships among input solar energy, output terrestrial energy and energy flow within the biosphere affect the lives of humans and other species		Unit D: Energy Flow in Global Systems: Outcomes for STS/K 4. investigate and identify human actions affecting biomes that have a potential to change climate (e.g., emission of greenhouse gases, draining of wetlands, forest fires, deforestation) and critically examine the evidence that these factors play a role in climate change (e.g., global warming, rising sea level(s))		Unit D: Energy Flow in Global Systems: Outcomes for STS/K 1. explain how climate affects the lives of people and other species, and explain the need to investigate climate change		Education, Alberta. (2014). Science 10-20: Program of Studies. Retrieved from http://education.alberta.ca/media/654833/science10.pdf.
	Unit D: Energy Flow in Global Systems: Outcomes for STS/K 2. Analyze the relationships among net solar energy, global energy transfer processes—primarily radiation, convection and hydrologic cycle—and climate.				Unit D: Energy Flow in Global Systems: Outcomes for STS/K 3. identify the potential effects of climate change on environmentally sensitive biomes		
					Unit D: Energy Flow in Global Systems: Outcomes for STS/K 4. assess, from a variety of perspectives, the risks and benefits of human activity, and its impact on the biosphere and the climate		
	Science 20	**Chemistry 30**					

Alberta	General Outcome 4: Students will analyze the evidence of, and assess the explanations for, natural variations in Earth's climate over the last two million years.	C2.3s investigate the issue of greenhouse gases; identify some greenhouse gases, including methane, carbon dioxide, water and dinitrogen oxide (nitrous oxide) and analyze their contribution to climate change					Education, Alberta. (2014b). Science 20-30: Program of Studies. Retrieved from http://education.alberta.ca/media/654837/sci2030_07.pdf.
British Columbia	**Science Grade 10**		**Science Grade 10**		**Science Grade 10**		MOEd, BC. (2008). Science Grade 10: Integrated Resource Package 2008. Retrieved from https://www.bced.gov.bc.ca/irp/pdfs/sciences/2008sci_10.pdf.
Grade 10 science is mandatory for graduation	D3 describe how natural phenomena can affect climate (e.g., biosphere processes, volcanic eruptions, Coriolis effect, El Niño and La Niña)		D3 describe how climate can be influenced by human activities (e.g., greenhouse gases, depletion of ozone layer)		D3 describe how climate change affects natural systems (e.g., shrinking of the permafrost region, melting of ice shelves/caps/glaciers)		
Manitoba	**Grade 10 Science**		**Grade 10 Science**		**Grade 10 Science**		Education, Manitoba. (2001). Senior Science 2: Specific Learning Outcomes. Winnipeg, Manitoba: Retrieved from http://www.edu.gov.mb.ca/k12/cur/science/outcomes/s2/slo.pdf.
Grade 10 science is mandatory for graduation	S2-4-02 Outline factors influencing the Earth's radiation budget.		S2-4-07 Investigate and evaluate evidence that climate change occurs naturally and can be influenced by human activities.		S2-4-08 Discuss potential consequences of climate change		
	S2-4-03 Explain effects of heat transfer within the atmosphere and hydrosphere on the development and movement of wind and ocean currents.						
New Brunswick	**Grade 10 Science**						Education, Department of. (2002). Science Grade 10. Retrieved from http://www.gnb.ca/0000/publications/curric/grade10science.pdf.
	(331-3) describe examples that illustrate that the atmosphere and hydrosphere are heat sinks in the water cycle.						

New Brunswick	(318-1) illustrate the cycling of matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen, and oxygen						
	Introduction to Environmental Science 120	**Introduction to Environmental Science 120**			**Introduction to Environmental Science 120**		DEECD. (2012). Introduction to Environmental Science 120 Curriculum. Retrieved from http://www.gnb.ca/0000/publications/curric/IntroductiontoEnvironmentalScience120Curriculum.pdf.
The unit on Climate Change in the Introduction to Environmental Science 120, is one of several units that can be chosen.	Optional Unit 3: Climate Change: distinguish between the greenhouse effect, global warming and climate change.	Optional Unit 3: Climate Change: describe how Earth's climate has changed in the short and long term, and how scientists have studied these changes.			Optional Unit 3: Climate Change: identify possible effects of climate change on NB. Include ecosystem changes, community effects, economic impact, cultural and social impacts.		
	Physical Geography 110						Education, Department of. (1994). Physical Geography 110: Portrait of a Planet. Fredericton, NB: Retrieved from https://www.gnb.ca/0000/publications/curric/PhysicalGeography110.pdf.
	Identify and explain the factors which control climate						
	Explain regional and chronological variations in world climate.						
Newfoundland and Labrador			**Environmental Science 3205**		**Environmental Science 3205**	**Environmental Science 3205**	DEECD. (2010). Environmental

Science 1206 is mandatory for graduation. *This objective comes from one of three optional units that teachers can choose from in this part of the course.			3.60 identify environmental impacts associated with the raising of livestock and poultry. Include: i) impacts on water quality ii) reduction of biodiversity iii) impacts of climate *		5.17 identify that climate change can have a catastrophic affect [*sic*] on Earth. Include: (i) natural sources of greenhouse gasses [*sic*] (ii) anthropogenic sources of greenhouse gases	5.25 describe efforts made to address climate change. Include: (i) individual (ii) industries (iii) provincial governments (iv) federal governments (v) international agreements such as the Rio Declaration and the Kyoto Protocol.	Science 3205 Curriculum Guide (Interim Edition). St. John's, NL: Retrieved from http://www.ed.gov.nl.ca/edu/k12/curriculum/guides/science/envsci3205/ES3205_Unit_5.pdf.
			5.17 identify that climate change can have a catastrophic affect [*sic*] on Earth. Include: i) natural sources of greenhouse gasses (*sic*) ii) anthropogenic sources of greenhouse gases		5.18 describe the impacts of climate change in Canada on wildlife and natural ecosystems. Include: (i) types of vegetation (ii) shifting ecosystem boundaries (iii) biodiversity of species (iv) adaptation of species		
					5.19 describe the impacts of climate change in forests		
					5.20 describe the impacts of climate change in Canada on agriculture. Include: (i) length of growing season (ii) extreme weather events (iii) types of crops (iv) precipitation variability		
					5.21 describe the impacts of climate change in Canada on fishery. Include: (i) water temperature (ii) species distribution (iii) growth rates		DEECD. (2014). Science. from http://www.ed.gov.nl.ca/edu/k12/curriculum/guides/science/#sc

Newfoundland and Labrador					5.22 describe the impacts of climate change in Canada on coastal zones (sea level changes and areas of human habitat). Include: (i) coastal erosion (ii) flooding due to expansion of ocean water caused by melting ice (iii) tectonic subsidence to (iv) Newfoundland and Labrador locations at risk		i1206
	Science 1206	**Science 1206**			5.23 describe the impacts of climate change in Canada on extreme weather events.. Include: (i) frequency (ii) intensity (iii) vulnerable areas in Newfoundland and Labrador		
	(115-6) explain how scientific knowledge evolves about changing weather patterns with new evidence about changes in ocean temperature - identify why oceans are important in weather dynamics - identify factors that are responsible for causing ocean currents	(318-1) illustrate the cycling of matter through biotic and abiotic components of an ecosystem by tracking carbon, nitrogen and oxygen - describe the processes required to cycle from carbon reservoirs to the atmosphere - describe the importance of oxygen to ecosystems - describe the significance of global warming and eutrophication			5.24 describe the impacts of climate change in Canada on human health. Include: (i) heat stress (ii) migration of diseases		
**Included especially because supporting documents make links to present day climate change for this objective.	**Earth Systems 3209**						
	(332-7) recognize that life forms, climate, continental positions and Earth's crust have changed over time **						
Northwest Territories	Uses the same science curriculum as Alberta.						

Nova Scotia Science 10 is mandatory for graduation	**Science 10** (331-3) describe how the atmosphere and hydrosphere act as heat sinks in the water cycle						DEECD. (2012b). Science 10: A Teaching Resource. Retrieved from http://www.ednet.ns.ca/files/curriculum/Science10TR.pdf.
Not all curriculum documents from Nova Scotia (Geology 12, Food Science) were accessible on government websites, though personal communications with educators from NS suggest that Food Science has no related objectives and Geology 12 is rarely made available to students.	**Oceans 11** OSM-5 explain the role of the Coriolis Effect in the relationship between wind and current direction OSM-6 - explain how thermohaline currents are produced						
Nunavut	Amongst other curriculum documents, Nunavut uses Science 10, Science 20 and Chemistry 30 from Alberta						
Ontario	**SNC2D**	**SNC2D**	**SNC2D**		**SNC2D**	**SNC2D**	MEDU. (2008). The

Either SNC2D or SNC2P is mandatory	D2.2 design and build a model to illustrate the natural greenhouse effect, and use the model to explain the anthropogenic greenhouse effect	D2.4 investigate a popular hypothesis on a cause-and-effect relationship having to do with climate change (e.g., the combustion of fossil fuels is responsible for rising global temperatures; the concentration of atmospheric CO2 is responsible for rising global temperatures; global temperatures have been on the increase since the industrial revolution; the severity of cyclones, hurricanes, and tornadoes increases as atmospheric temperatures increase), using simulations and/or time-trend data that model climate profiles (e.g., data from Statistics Canada and Environment Canada)	D2 Investigate various natural and human factors that have an impact on climate change and global warming		D1 analyse some of the effects of climate change around the world, and assess the effectiveness of initiatives that attempt to address the issue of climate change;	D1 analyse some of the effects of climate change around the world, and assess the effectiveness of initiatives that attempt to address the issue of climate change;	Ontario Curriculum Grades 9 and 10: Science. Toronto: Queen's Printer for Ontario Retrieved from http://www.edu.gov.on.ca/eng/curriculum/secondary/science910_2008.pdf.

Question numbers which are relevant to specific expectations in the Ontario curriculum are indicated in bold at the end of those expectations.	D2.5 investigate, through laboratory inquiry or simulations, the effects of heat transfer within the hydrosphere and atmosphere	D3.8 identify and describe indicators of global climate change (e.g., changes in: glacial and polar ice, sea levels, wind patterns, global carbon budget assessments)	D3 demonstrate an understanding of natural and human factors, including the greenhouse effect, that influence Earth's climate and contribute to climate change.		D1.1 analyse current and/or potential effects, both positive and negative, of climate change on human activity and natural systems (e.g., loss of habitat for Arctic mammals such as polar bears and loss of traditional lifestyles for Inuit as Arctic ice shrinks; famine as arable land is lost to desertification; an increase in water-borne disease and human resettlement as coastal lands are flooded; expansion of the growing season in some regions)	D1.2 assess, on the basis of research, the effectiveness of some current individual, regional, national, or international initiatives that address the issue of climate change (e.g., Drive Clean, ENERGY STAR, federal and provincial government rebates for retrofitting older buildings to be more energy efficient, carbon offset programs, community tree-planting programs, municipal recycling programs, Intergovernmental Panel on Climate Change [IPCC]), and propose a further course of action related to one of these initiatives	MEDU. (2008b). The Ontario Curriculum Grades 11 and 12: Science. Toronto: Queen's Printer for Ontario Retrieved from http://www.edu.gov.on.ca/eng/curriculum/secondary/2009science11_12.pdf.

Ontario	D2.6 investigate, through laboratory inquiry or simulations, how water in its various states influences climate patterns (e.g., water bodies moderate climate, water vapour is a greenhouse gas, ice increases the albedo of Earth's surface)		D2.3 analyse different sources of scientific data (e.g., lake cores, tree rings, fossils and preserved organisms, ice cores) for evidence of natural climate change and climate change influenced by human activity				
	D2.7 investigate, through research or simulations, the influence of ocean currents on local and global heat transfer and precipitation patterns		D3.3 describe the natural greenhouse effect, explain its importance for life, and distinguish it from the anthropogenic greenhouse effect				
	D3.1 describe the principal components of Earth's climate system (e.g., the sun, oceans, and atmosphere; the topography and configuration of land masses) and how the system works		D3.4 identify natural phenomena (e.g., plate tectonics, uplift and weathering, solar radiance, cosmic ray cycles) and human activities (e.g., forest fires, deforestation, the burning of fossil fuels, industrial emissions) known to affect climate, and describe the role of both in Canada's contribution to climate change				
	D3.2 describe and explain heat transfer in the hydrosphere and atmosphere and its effects on air and water currents		D3.5 describe the principal sources and sinks, both natural and/or anthropogenic, of greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide, halocarbons, water vapour)				

Ontario	D3.6 describe how different carbon and nitrogen compounds (e.g., carbon dioxide, methane, nitrous oxide) influence the trapping of heat in the atmosphere and hydrosphere		D3.7 describe, in general terms, the causes and effects of the anthropogenic greenhouse effect, the depletion of stratospheric and tropospheric ozone, and the formation of ground-level ozone and smog				
	SNC2P	**SNC2P**	**SNC2P**		**SNC2P**	**SNC2P**	
	D3 demonstrate an understanding of various natural and human factors that contribute to climate change and global warming.	D1 analyse effects of human activity on climate change, and effects of climate change on living things and natural systems;	D2 investigate various natural and human factors that have an impact on climate change and global warming;		D1.1 analyse, on the basis of research, various ways in which living things and natural systems have been affected by climate change (e.g., the effect of loss of permafrost on northern roads and housing; the effect of longer growing seasons in some regions on farmers; the effect of warming oceans on coral reefs), and communicate their findings	D1.2 analyze ways in which human actions (e.g., burning fossil fuels, implementing tree-planting programs) have increased or decreased the production of greenhouse gases	

Ontario	D2.2 investigate the principles of the natural greenhouse effect, using simulations, diagrams, and/or models, and compare these principles to those of an actual greenhouse	D2.4 conduct an inquiry to determine how different factors (e.g., an increase in surface temperature, an increase in water temperature) affect global warming and climate change	D3 demonstrate an understanding of various natural and human factors that contribute to climate change and global warming.		D2.3 use a research process to investigate a source of greenhouse gases (e.g., decaying garbage, animal digestive processes, burning biomass) and its effect on a region of Canada (e.g., melting of the polar ice cap in the Arctic, shrinking of glaciers in the Rockies)	D2.5 investigate their personal carbon footprint, using a computer simulation or numerical data (e.g. determine carbon emissions that result from their travelling to school, work, and recreation venues; from vacation travelling; from buying products imported from distant countries), and plan a course of action to reduce their footprints (e.g., a plan to increase their use of bicycles or public transit; to eat more local)	
	D3.1 describe the principal components of Earth's climate system (e.g., the sun, oceans, and atmosphere; the topography and configuration of land masses) and how the system works	D3.7 identify indicators of global climate change (e.g., changes in: the mass of glacial and polar ice, sea levels, wind patterns, global carbon budget assessments, migratory patterns of birds)	D1.2 analyse ways in which human actions (e.g., burning fossil fuels, implementing tree-planting programs) have increased or decreased the production of greenhouse gases				

Ontario	D3.2 describe the natural greenhouse effect, its importance for life, and the difference between it and the anthropogenic greenhouse effect		D2.3 use a research process to investigate a source of greenhouse gases (e.g., decaying garbage, animal digestive processes, burning biomass) and its effect on a region of Canada (e.g., melting of the polar ice cap in the Arctic, shrinking of glaciers in the Rockies)				
	D3.3 describe how heat is transferred and stored in both hydrospheric and atmospheric heat sinks		D3.2 describe the natural greenhouse effect, its importance for life, and the difference between it and the anthropogenic greenhouse effect				
	D3.4 identify different greenhouse gases (e.g., carbon dioxide, methane, water vapour, nitrous oxide), and explain how they are produced naturally in the environment		D3.5 describe methods by which greenhouse gases are produced by humans (e.g., burning of biomass, chemical reactions involving pollutants)				
			D3.6 identify the natural and human causes of climate change in the world and, in particular, how Canada contributes to climate change				
	SES4U				**SBI3U**		
	D1 analyse, with reference to geological records, the relationship between climate, geology, and life on Earth, and evaluate contributions to our understanding of				B1.2 analyse the impact that climate change might have on the diversity of living things (e.g., rising temperatures can result in habitat loss or expansion; changing rainfall levels can cause drought		

Ontario	changes in Earth systems over geological time;				or flooding of habitats)		
	D1.1 analyse the relationship between climate and geology, and, using geological records, assess the impact of long-term climate change on life on Earth						
Prince Edward Island	**Grade 10 Science 421A/431A**						DEECD. (2011). Environmental Science 621A. Summerside, Prince Edward Island: Retrieved from http://www.gov.pe.ca/photos/original/eecd_ENV621A.pdf.
Grade 10 Science is mandatory for graduation	(331-1) describe and explain heat transfer within the water cycle						
	(331-3) describe how the hydrosphere and atmosphere act as heat sinks within the water cycle						
	Environmental Science 621	**Environmental Science 621**	**Environmental Science 621**		**Environmental Science 621**	**Environmental Science 621**	
Prince Edward Island	6.2 demonstrate an understanding of how Earth's climate has changed over time	6.6 identify the effects that climate change can have on Prince Edward Island - sea level rise - increased erosion - economic effects - social effects - species movement/loss	6.3 demonstrate an understanding of the greenhouse gases found in the troposphere and atmosphere - natural sources of greenhouse gases - anthropogenic sources of greenhouse gases		6.5 identify that climate change can have a catastrophic effect on Earth.	6.8 demonstrate an understanding of challenges and successes made to address climate change - individual - industries -	DEECD. (2005). Science 421A. Prince Edward Island: Retrieved from http://www.gov.pe.ca/photos/original/ed_sci421Aguide.pdf.

						provincial governments - federal governments - international agreements	
	6.4 distinguish between the greenhouse effect and global warming				6.6 identify the effects that climate change can have on Prince Edward Island - sea level rise - increased erosion - economic effects - social effects - species movement/loss		
Quebec	**Secondary 4 Science and Technology**	**Secondary 4 Science and Technology**	**Secondary 4 Science and Technology**		**Secondary 4 Science and Technology**		
Either Science and Technology or Applied Science and Technology is mandatory for graduation. Quebec also has an optional program called CEGEP which is a pre-university program resulting in secondary education being a year shorter. Analysis of this program was not included in this study.	Because of their ability to absorb heat, the oceans play an essential role in regulating climate by standardizing the temperature of the Earth.	Climate change is one of the major challenges humanity will have to face. The most urgent problem is the average temperature of the Earth.	By burning enormous quantities of fossil fuels (coal, oil and natural gas), which generate a significant amount of CO2, and by clear-cutting forests, which hampers the natural process of CO2 transformation, we magnified the natural greenhouse effect and we are now experiencing an increase in Earth's temperature.		The permafrost is sensitive to climate change because the underground ice it contains is unstable. Warming of the permafrost can cause landslides and damage to infrastructures and alter the landscape and ecosystems.		MELS. (2014). Quebec Education Program: Mathematics, Science and Technology. Retrieved February 12, 2015, from http://www1.mels.gouv.qc.ca/sections/programmeFormation/secondaire2/index_en.asp?page=math2

Quebec			Today, we are using vast quantities of nonrenewable and polluting forms of energy. This has a serious impact on the environment and especially on our climate, which raises the question of the environment's ability to adapt.		Climate change is one of the major challenges humanity will have to face. The most urgent problem is the average temperature of the Earth.		
			Carbon dioxide is the most abundant greenhouse gas. Its proportion has increased over the past century because of the use of fossil fuels and the manufacture of cement.		In Québec, climate change could affect the quality of our water, endangering human health and the balance of ecosystems. It could also cause fluctuations in the level of the Great Lakes and the flow of the St. Lawrence River. These fluctuations would have various consequences for the marine transportation industry, which relies on the St. Lawrence Seaway. They would also disrupt certain ecosystems, through habitat loss or deteriorating living conditions for some species of fish.		
	Applied Science and Technology		**Applied Science and Technology**		Variations in precipitation would undoubtedly affect agricultural productivity and biodiversity in Québec. Moreover, costal erosion and more frequent freezes and thaws would have an impact on the road network.		
	The carbon cycle is regulated by the interaction of continental plates, the atmosphere, the oceans and living organisms. Although plants use photosynthesis to fix		Certain objects, systems and products (gasoline engine, petroleum products) that meet our needs also have negative consequences. Meteorological data collected in the past fifty years show climate changes at least partly due to the use of		Finally, if permafrost thaws, soils in the far north could become unstable, affecting populations there.		

Quebec	carbon in nonvolatile forms, carbonate rock, precipitated or created by living beings, constitutes the largest reserve of CO2.While this gas is released during volcanic eruptions, anthropogenic emissions restore the natural balance. Certain environmental biotechnologies contribute to the chemical recycling of carbon.		such objects systems and products.				
Saskatchewan	**Science 10**	**Science 10**	**Science 10**		**Science 10**	**Science 10**	Education, Ministry of. (2014a). Science 10. Retrieved from https://www.edonline.sk.ca/bbcswebdav/library/curricula/English/Science/Science_10_2014_outind_only.pdf.
Science 10 is mandatory for graduation. The newer curriculum guides which were introduced for the 2014/2015 school year, were used instead of older documents.	SCI10-CD2 Investigate factors that influence Earth's climate system, including the role of the natural greenhouse effect.	SCI10-CD1h Research how scientists examine changes to the key indicators of climate change (e.g. CO2 concentration, global surface temperature, Arctic sea ice area, land ice mass, and sea level) to support the scientific understanding of climate change.	SCI10-CD1 Assess the consequences of human actions on the local, regional, and global climate and the sustainability of ecosystems		SCI10-CD1a Pose questions or problems relating to the effects of human actions on global climate change and the sustainability of ecosystems that arise from personal research	SCI10-CD1i Reflect upon individual and societal behavioural and lifestyle choices that can help to minimize anthropogenic sources of climate change.	

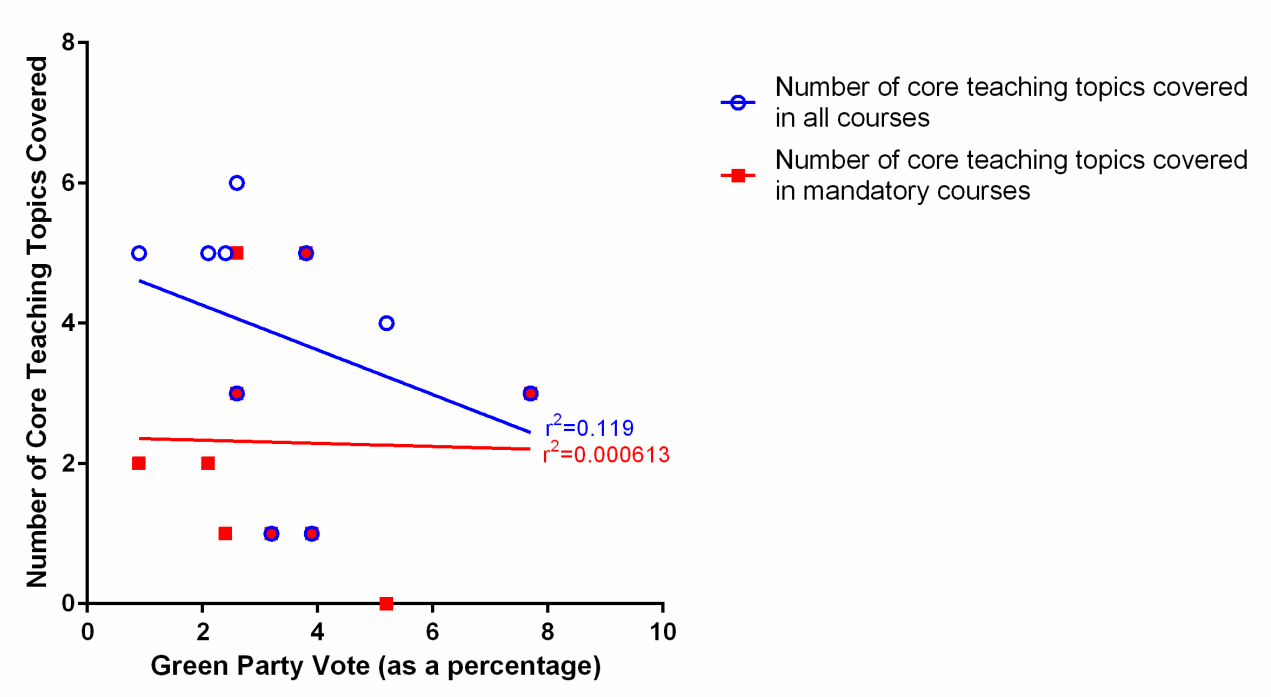
Saskatchewan	SCI10-CD2b Understand that Earth's climate system results from the exchange of thermal energy and moisture between the sun, ice sheets, oceans, solid earth, and the biosphere over a range of timescales.		SCI10-CD1g Provide examples of human actions that have contributed to the anthropogenic greenhouse effect		SCI10-CD1k Assess the current and potential future effects of ongoing changes to Earth's climate systems on the people and the environment in Saskatchewan and Canada's Arctic region	SCI10-CD1j Develop, present, and defend a position or course of action based on personal research related to mitigating the effects of global or local climate change or to enhancing the sustainability of an ecosystem, taking into account human and environmental needs.	
	SCI10-CD2c Investigate how Earth's tilt, rotation, and revolution around the sun cause uneven heating of Earth's surface, resulting in global convection currents, the Coriolis effect, jet streams, thermohaline circulation of the oceans, and climate zones.						

Saskatchewan	SCI10-CD2e Explain how greenhouse gases (e.g., water vapour, carbon dioxide, methane, nitrous oxide, sulphur dioxide, and ozone), particles and clouds, and surface albedo affect the amount of solar energy absorbed and reradiated at various locations on Earth.						
	SCI10-CD2e Provide examples of positive and negative feedback mechanisms in Earth's climate system						
	Environmental Science 20	**Environmental Science 20**	**Environmental Science 20**	**Environmental Science 20**	**Environmental Science 20**	**Environmental Science 20**	
	ES20-TE1f Analyze the relationship between plants and climate change, including plants' roles in reducing greenhouse gases, as well as potential impacts of climate change on plant growth and distribution.	ES20-AS2b Explore, on a variety of spatial and temporal scales, major physical, biological, and social indicators of increasing global temperatures.	ES20-AS2c. Examine the role of policies, summits, models, and organizations, such as the Canadian Centre for Climate Modeling and Analysis (CCCma), Intergovernmental Panel on Climate Change (IPCC), and Prairie Adaptation Research Collaborative (PARC), in obtaining a high degree of consensus among scientists regarding anthropocentric climate change.	ES20-AS2c. Examine the role of policies, summits, models, and organizations, such as the Canadian Centre for Climate Modeling and Analysis (CCCma), Intergovernmental Panel on Climate Change (IPCC), and Prairie Adaptation Research Collaborative (PARC), in obtaining a high degree of consensus among scientists regarding anthropogenic climate change.	ES20-AS2 Analyze current and potential future effects of global climate change on Earth and humans, including the need for adaptation and mitigation strategies.	ES20-AS2 Analyze current and potential future effects of global climate change on Earth and humans, including the need for adaptation and mitigation strategies.	Education, Ministry of. (2014b). Environmental Science 20. Retrieved from https://www.edonline.sk.ca/bbcswebdav/library/curricula/English/Science/Environmental_Science_20_2014.pdf.

Saskatchewan					ES20-AS2e. Explain the economic impact of climate change on agriculture, energy, forestry, transportation, and/or tourism in Saskatchewan.	ES20-AS2f Examine how policy makers use scientific information, including climate model predictions, to develop adaptation and mitigation strategies to respond to the effects of climate change.	
					ES20-AS2h. Hypothesize how life on Earth might respond to changing global climate given different scenarios change such as sea level rise, extreme weather events, water shortages, increased spread of disease, and flooding.		
					ES20-TE2d Discuss the implications of the competitive exclusion principle with respect to animals and plants in an ecosystem, including the invasive species and the potential for shifting ecozones due to climate change.		
Yukon	Uses the same curriculum as British Columbia						

Appendix D: Coverage of climate change in curricula versus Green Party voting

Coverage of climate change in provincial curricula versus the percentage of a province's federal vote that went to the Green Party of Canada is used here as a way to compare political tendencies of a province with climate change education. If political leanings of a province affected curricular content we would expect a positive correlation for Green Party voting and the number of core teaching topics covered. Visually, and from the r^2 values, we can see that no relationship is evident.



Appendix E: Canada's emissions targets over time

Canada's present and target future greenhouse gas emissionswith emissions values for 2012 and 2013 from the CDIAC (Boden et al., 2013) using predictions from BP (2014), with 2014 onwards following the 7% annual reduction suggested by Raupach et al. (2014) for North America. Population values from Statistics Canada (2014b) are extrapolated based on a 1.1% growth rate which was also provided by Statistics Canada (2014a).

Year	GHG Emissions ($MtCO_2e$)	Population (millions)	Emissions per capita (tCO_2e)
2012	498.30	34.75	14.34
2013	501.97	35.15	14.28
2014	466.83	35.54	13.14
2015	434.15	35.93	12.08
2016	403.76	36.33	11.11
2017	375.50	36.73	10.22
2018	349.21	37.13	9.41
2019	324.77	37.54	8.65
2020	302.03	37.95	7.96
2021	280.89	38.37	7.32
2022	261.23	38.79	6.73
2023	242.94	39.22	6.19
2024	225.94	39.65	5.70
2025	210.12	40.08	5.24
2026	195.41	40.53	4.82
2027	181.73	40.97	4.44
2028	169.01	41.42	4.08
2029	157.18	41.88	3.75
2030	146.18	42.34	3.45

Appendix F: Teaching Resources

more effective than recycling High Impact Actions: Teaching Guide

Resources: Powerpoint projector, high impact fact sheets, 2 colours of sticky notes, small, erasable white boards

Background: Students should be familiar with CO_2, the issue of climate change, and the role of greenhouse gases

Opener (5 min): Show the first powerpoint slide. Using sticky notes, ask students to write the numbers 1 and 2 on two different sticky notes. Students should come up to the board and lace their number 1 sticky note on top of the action that they think would be the most effective way to reduce a person's impact on the climate, and the second sticky note on the second best action. Then skip to slide 2 to show the students which are actually the highest impact actions. The students should be able to easily see which actions they thought were the most effective versus actions that are actually the most effective. Discuss.

Jigsaw Activity (15-20min): Split students up into groups. Each group should include as many students as there are high impact action fact sheets being used. Students receive a number and then go to work on the fact sheet corresponding with their number. Students are to read the sheet, note down important information and answer questions to bring back to their original group (they become "experts" on this particular action). Once back in their original groups, students should explain what they learned to other group members who can take notes.

Information that "expert" students could be asked to bring back to their groups, and potential answers:

1) What makes this action "high impact"? Why for instance, does it have more effect on climate change than turning off a lightbulb?
Car ownership: Cars take a lot of energy to manufacture and to drive. Cars are inefficient because only 5% of the weight they need to move is made of passengers and what they carry.
Plant-based diet: Cows produce methane which is a strong greenhouse gas. It takes much more land to feed animals than it would take if we just ate plants. This requires more fertilizer/pesticides etc. Meat is also at the top of the energy pyramid, making it less efficient.
Air travel: Planes use more fuel/make more CO_2 to move the same amount of stuff. Planes release other chemical such as nitrous oxides that warm the earth more than CO_2 would on its own. Jet fuel is highly refined and it takes a lot of energy to fight gravity.
Fewer children: Each child will go on to produce a lifetime's worth of CO_2 in all areas (transport, food etc.). Each child may also have their own children (not on sheet).

2) Are there any helpful suggestions for carrying out this action? Are there any benefits other than helping the environment?
Car ownership: Take public transit, bike, walk. Not driving is usually healthier and contributes to cities that are better places to live in.
Plant-based diet: A plant-based diet can be better for your health (less risk of diabetes, death from heart disease etc.) and treats animals ethically.
Air travel: Use a webcam for meetings or staying in touch with family instead of flying. Travelling by train is another alternative and can even be faster than flying in some cases.
Fewer children: Allows you to focus more on your career and maintain personal freedom.

High Impact Action: Teaching Guide

3) Are there political ways to get involved with this issue?
Car ownership: Talk to city councillor to encourage the creation of bike lanes and public transit.
Plant Based diet: None given. Students might come up with their own such as 'encourage friends and family to eat less meat'.
Air Travel: Contact government officials or start a petition to get high speed railways.
Fewer children: Vote for politicians that care about the environment or join an organization that supports sustainability.

Group quiz competition (5 min): The remaining slides on the powerpoint presentation ask questions about the material learned so far in multiple choice format. Since each group has one student who is an expert all questions should be answerable. Ideally, each group should have an erasable white board to show their answers on so that you can keep track of their scores. Students are encouraged to work together with group mates in this section.

Helpful Knowledge for teachers

The Graph: Data for having a child is based on one child in the United states and includes the children that they will probably have, with responsibility for emissions given to the parent according to genetics (1/2 responsibility for a child, 1/4 for grandchild etc.). Increasing a car's fuel economy is not included as a high impact action because it's hard to know if buying a more efficient car is better when it means more emissions for manufacturing a new car - ideally we shouldn't drive at all. Eating a plant based diet is based on a shift from an average omnivorous diet to either a vegan or vegetarian diet. Recycling includes paper, glass, aluminum cans etc. Upgrade light bulbs means switching ten incandescent light bulbs to CFLs.
The comparisons to recycling on each handout are based on the numbers used in the Ppt graph: one year of recycling all major household products (glass, newspaper, aluminum cans etc.) versus: a transatlantic flight, owning an average car for a year, eating an average of vegan and vegetarian diets for a year, and the footprint of one individual (as calculated above and divided over an 80 year lifespan).

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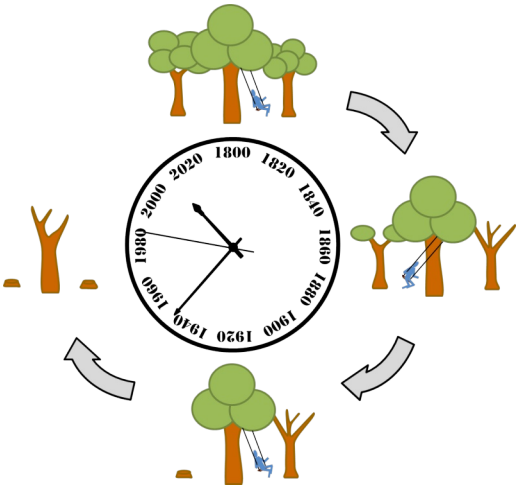
555 more effective than recycling

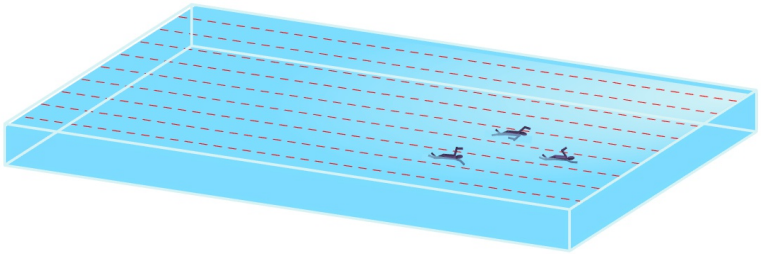
High Impact Action: Have one fewer child

You don't need to give birth to get the experience of having children. Many people find that fostering, adopting, or helping to raise nieces and nephews also brings fulfillment.



Intergenerational justice means being fair to future generations. This requires us to leave them with the same resources and the same healthy planet that we got when we were born. It's never fair for one person to live in another person's mess. You can contribute to intergenerational justice by voting for politicians who care about the environment or joining organizations that promote sustainability. Whether you have kids or not, it's an idea worth considering.

In one lifetime a person can expect to use the equivalent of 1870 barrels of oil for their energy needs, eat 1185 chickens and produce 10.4 million kg of waste water (that's 4 olympic swimming pools of waste).



About 1/5 women don't have children by the time they're 40, and most of them do this by choice. People might choose to be 'childfree' so that they can focus on their career, keep their personal freedom or so that they don't pass on a certain genetic trait. Research has shown that young adults also consider not having kids because they are worried about raising children on a polluted planet.

If it is irresponsible, in a warming world, for an individual to drive a Hummer that gets six miles per gallon of gasoline, it is irresponsible for him to father six children—each of whom will generate much more greenhouse gas emissions during the course of his or her lifetime than the car. - Philip Cafaro

Do you agree or disagree with this statement? Is having children and owning a car comparable in this case?

12 000 000

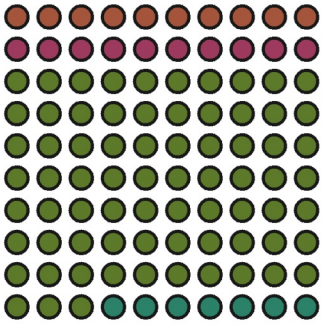
To offset the carbon emissions that a human will produce in their lifetime, you would have to plant 6700 sugar maple trees or recycle 12 million aluminum cans. For most people, choosing to have one fewer child is the action that will have the greatest impact on the environment.

11x more effective than recycling

High Impact Action: Live car free

Can't I just get a hybrid?

If you don't drive your car much, you won't burn much carbon, right? Wrong! The average car makes about 100 tons of CO_2, starting when it's in the factory until you stop driving it. And 10 tons alone is used to manufacture the car. That's more CO_2 than two people in Ecuador produce in a whole year! Getting a car means lots of emissions - there's just no way driving around it!



Manufacturing
Refining the fuel
Running the vehicle
Maintenance/other

Total=100.23

Only *5%* of a car's weight is from passengers and what they carry! If you weighed 50kg - how much energy would you waste peddling a 950kg bike? Could you even move it? This is why cars are so inefficent, and why they make so much CO_2.

Young people travel light

Far more young people in North America are choosing to go without a car than their parents' generation did at the same age. They do this by living close to where they work, in walkable neighbourhoods with good public transit. Using cellphones to figure out bus and train schedules makes their lives even easier. If there aren't bike lanes or good transit in your area then talk to your city councillor to get changes!

Parks vs parking lots

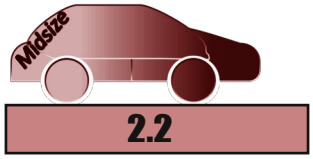
In cities made for cars, space that could be used for parks, shops and community centres is occupied by highways and parking lots. Vibrant cities are walkable!

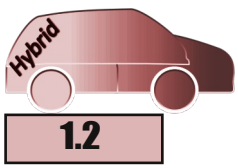
$11 000 - That's how much the average Canadian spends on transportation per year, and almost all of it is for personal vehicles. Using alternatives can save you thousands every year.

Stay fit! Each additional hour spent in a car per day adds 6% to the chance of becoming obese.

Cars create pollution and smog that's bad for our health.

If you absolutely have to...





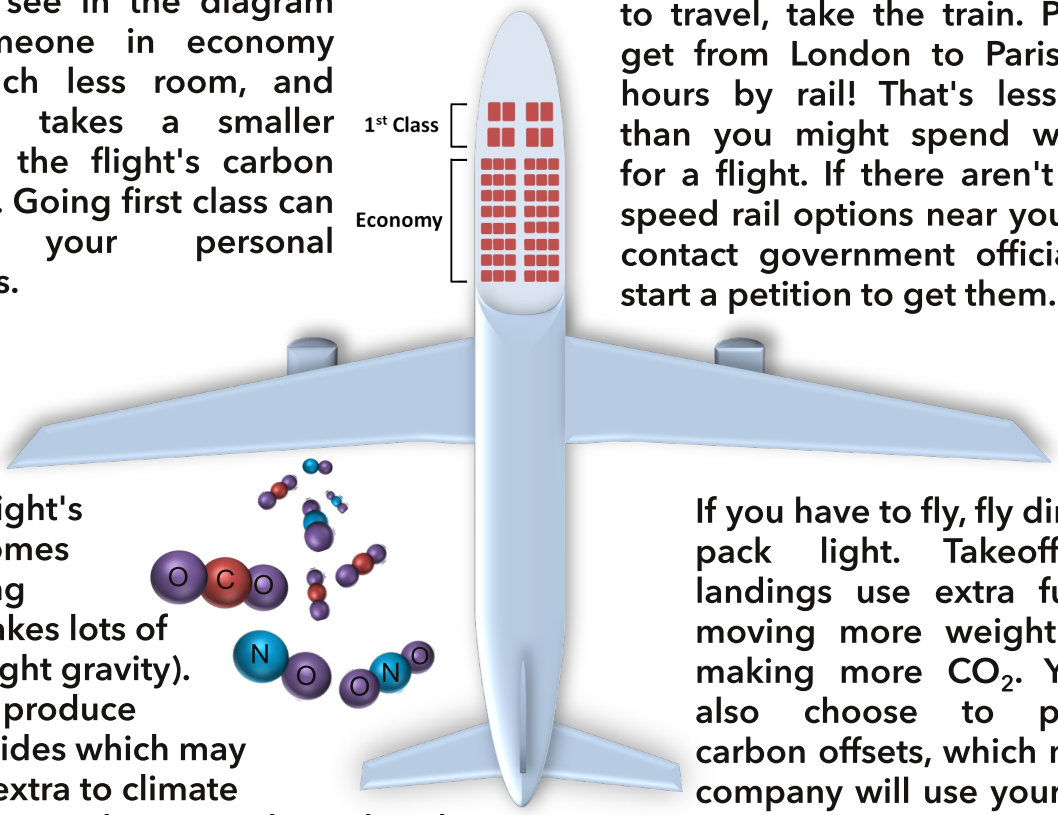
If you must have a car, then get one that's fuel efficient, share it, and drive as little as possible. This diagram shows the tonnes of CO_2 produced per year driving each vehicle. How much do you save by getting a hybrid instead of an SUV?

8x more effective than recycling

High Impact Action: Avoid air travel

As life becomes faster-paced, it can be worth slowing down to enjoy the journey. What sights and sounds might you miss when you're high in the air?

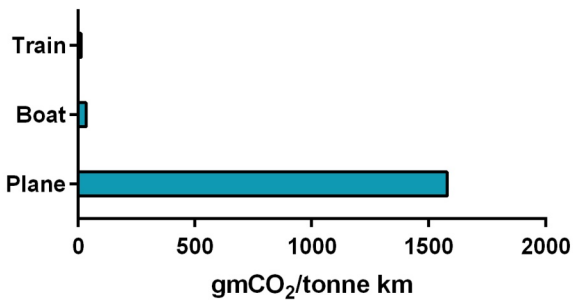
Carbon calculators will sometimes ask if your seat was economy or first class. You can see in the diagram that someone in economy uses much less room, and therefore takes a smaller share of the flight's carbon footprint. Going first class can double your personal emissions.



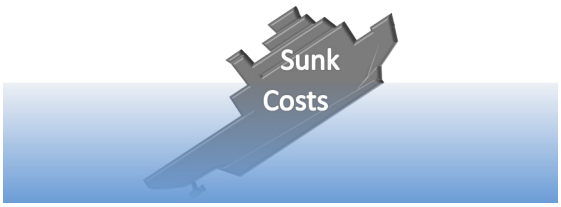
Use webcams to stay in touch with family and take vacations close to where you live instead of flying. Then, when you need to travel, take the train. People get from London to Paris in 2 hours by rail! That's less time than you might spend waiting for a flight. If there aren't high-speed rail options near you then contact government officials or start a petition to get them.

Most of a flight's footprint comes from burning jet fuel (it takes lots of energy to fight gravity). Planes also produce nitrogen oxides which may contribute extra to climate change because they are released in the upper atmosphere. We're not sure how strong their warming effect is, but it's worse than CO_2 would be on its own.

If you have to fly, fly direct and pack light. Takeoffs and landings use extra fuel and moving more weight means making more CO_2. You can also choose to purchase carbon offsets, which means a company will use your money to plant enough trees or install enough renewable energy to cover your emissions.



This graph shows how much carbon dioxide is emitted in order to move one tonne of material a full kilometer using different methods. You can see now why trains are so climate-friendly and why flying is the least eco-friendly way to travel.



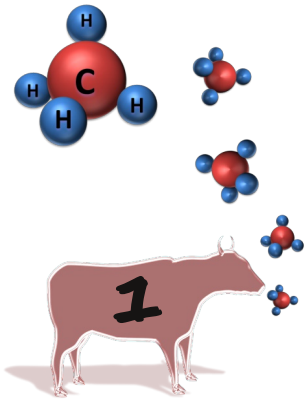
Though we might develop low-carbon flight in the future (biofuels, liquid hydrogen) for now we have "sunk costs" in our system. This means airports and planes are designed for fossil fuels, and no one wants to abandon expensive equipment if it still works. If you're waiting for sustainable air travel, don't hold your breath.

4x more effective than recycling

High Impact Action: Plant-based diet

Researchers have calculated that if we only grew crops to feed people (not for livestock or biofuels), we would create enough new calories for an extra **4 billion** people on Earth. With the world's population still expanding, it's time to think about changing our diet.

Cows produce a large amount of methane, or CH_4, which is a very strong greenhouse gas. In fact, this digestive process created the equivalent of **2 billion tonnes** of CO_2 in 2010. More than all of Canada put together!



It takes ten calories from plants to make one calorie of meat. That means extra land is used to feed animals that could be used for people. This requires more fertilizers, pesticides and deforestation than a system without meat.

Won't someone else just buy the meat?

Every time you buy a product you send a price signal to the company selling it, telling them to produce more. Boycotts work because enough people refusing to buy a product sends a strong message and changes what a company makes. And it goes both ways: there are four times more chickens in the world than fifty years ago because people eat more meat than they used to. What you buy matters - meat included.

Reasons to eat green

In recent years many news articles and films have documented inhumane conditions for animals in factory farms and slaughterhouses. If you're worried about animal cruelty then a plant-based diet is a reasonable first step.

Vegetarians also have a lower risk of death from heart disease, as well as lower rates of diabetes and cancer.

If you have to...

If you can't go without meat, try to choose poultry (chicken and turkey) over cow products. As you can see on the right, it can make a huge difference to your carbon footprint. You won't find fish on the graph because they can be anywhere between potatoes and beef (0.7 to 14kgCO_2e/kg).