Canada's Energy Outlook

CURRENT REALITIES AND IMPLICATIONS FOR A CARBON-CONSTRAINED FUTURE

CHAPTER 1: CANADIAN ENERGY CONSUMPTION IN THE GLOBAL CONTEXT
Full report available at energyoutlook.ca

By J. David Hughes

MAY 2018

CCPA
CANADIAN CENTRE
for POLICY ALTERNATIVES
BC Office

PARKLAND INSTITUTE

CORPORATE MAPPING PROJECT

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Hughes has published widely in the scientific literature and his work has been featured in *Nature, The Economist, LA Times, Bloomberg, USA Today* and *Canadian Business*, as well as other press, radio and television outlets. Recent reports for CCPA and PCI include the following: *Will the Trans Mountain Pipeline and tidewater access boost prices and save Canada's oil industry?* (CCPA, May 2017); *Shale Reality Check* (PCI, February 2018); *Can Canada increase oil and gas production, build pipelines and meet its climate commitments?* (CCPA, June 2016); *A Clear View of BC LNG* (CCPA, May 2015); *Drilling Deeper* (PCI, October 2014); *Drilling California*; (PCI, December 2013) and *Drill, Baby, Drill* (PCI, February 2013).

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Contents

Introduction to Part 1

In developing an energy strategy, it is first important to understand where Canadian energy comes from and how Canada compares to other countries in terms of total production and consumption by type of fuel. Primary energy consumption includes energy at the source before conversion to end-use forms such as electricity and refined petroleum products. Delivered energy (sometimes called secondary energy) is energy consumed at the point of use, and excludes losses such as those in converting fossil fuels to end-use electricity. A typical coal plant, for example, may have a conversion efficiency of just 33%, so 67% of the energy in the coal is lost in the conversion process.

The following chapter looks at primary and delivered energy consumption by fuel source and country, to put Canada in perspective as to the absolute level of consumption and the trends in consumption over the past few decades. It also looks at electricity generation and consumption, given that electricity is a particularly useful form of end-use energy and is the primary form of energy generated by renewables, which will be increasingly important in lowering greenhouse gas emissions in the future. The contribution of non-renewable energy production to government revenues in terms of royalties, corporate taxes, GDP and jobs is also examined.

1.1 Primary energy

Figure 1 (next page) illustrates per capita primary energy consumption for selected countries and geopolitical groupings in the world.[1] Canada is one of the highest per capita energy consumers, at 5.1 times the world average, and is considerably higher than the US. Developed countries, represented by the Organization for Economic Cooperation and Development (OECD), consume 3.4 times as much energy per capita as the rest of the world, and Canadians consume more than twice as much energy as the average citizen in the OECD. A major issue for the future is the aspiration of the developing world to consume energy at the rates of developed countries (non-OECD countries comprise 83% of world population). It is also interesting to note that developed nations like Germany, France, the United Kingdom and Japan consume energy at less than half the rate of Canadians.

[1] BP Statistical Review of World Energy, 2017. Note that the "oil equivalent" basis converts primarily electricity sources like hydro, nuclear, wind, solar and geothermal to "oil equivalent" at an electricity conversion efficiency of 38% to calculate the amount of oil that would have to be burned to generate that amount of end use electric energy, http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

Figure 1: Per capita primary energy consumption by country and fuel source in 2016.[2]

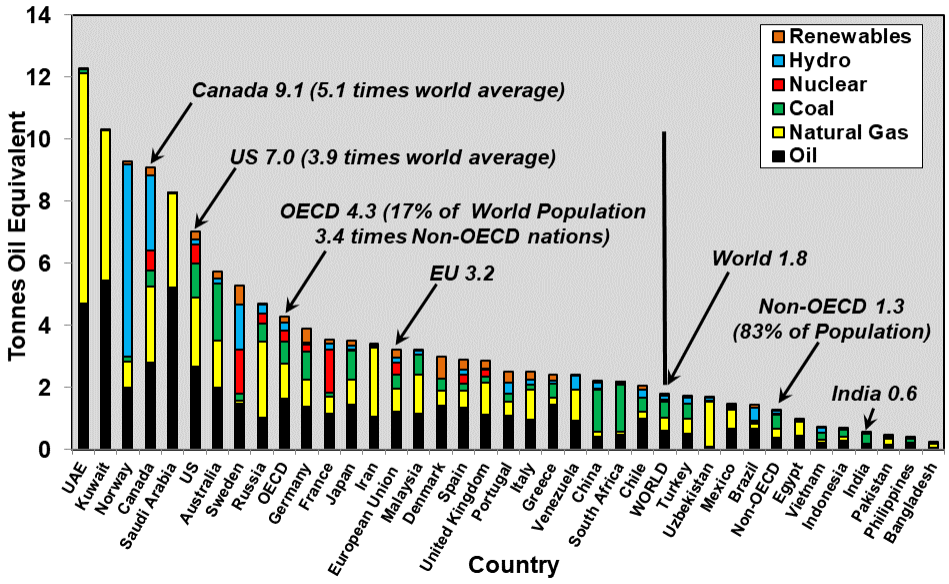
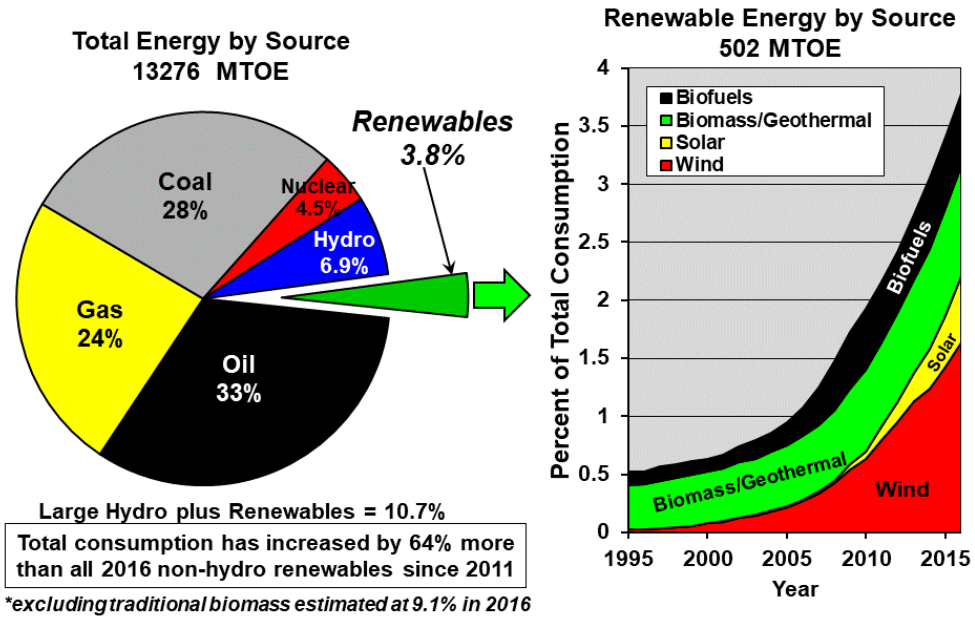


Figure 2 illustrates global energy consumption by fuel source in 2016. Fossil fuels accounted for 86%, with oil, coal and gas comprising 33%, 28% and 24%, respectively. Hydroelectric provided a further 6.9% followed by nuclear at 4.5%. Non-hydro renewable energy provided just 3.8%, even though it has grown exponentially in recent years. Notwithstanding the need to reduce global emissions from burning fossil fuels, they are likely to be part of the energy mix for the foreseeable future, given their utility and the scaling issues of non-hydro renewable energy.

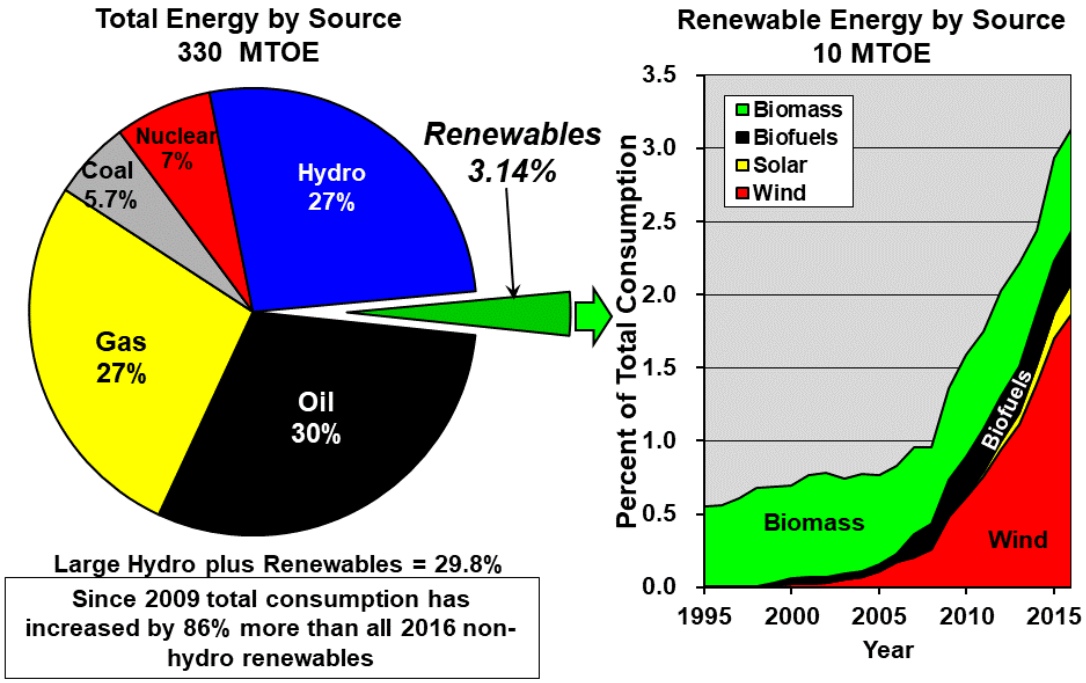
Figure 2: World primary energy consumption by fuel source in 2016, illustrating the evolution of non-hydro renewable energy from 1995 to 2016.
MTOE stands for "million tonnes oil equivalent."[3]



[2] Data from BP Statistical Review 2017 and World Bank population statistics for 2016
[3] Data from BP Statistical Review of World Energy, 2017; traditional biomass from REN21, 2017

Figure 3 illustrates Canadian energy consumption by fuel source in 2016. Although Canada has a far lower dependence on coal than the world as a whole, its dependence on oil and gas is the same, at 57%. Hydroelectricity is a major source of renewable energy in Canada, at 27% of primary energy consumption, compared to less than 7% in the world as a whole. Non-hydro renewable energy comprised 3.1% of Canadian consumption in 2016, two-thirds of which came from solar and wind.

Figure 3: Canada primary energy consumption by fuel source in 2016, illustrating the evolution of non-hydro renewable energy from 1995 to 2016.
MTOE stands for "million tonnes oil equivalent."[4]

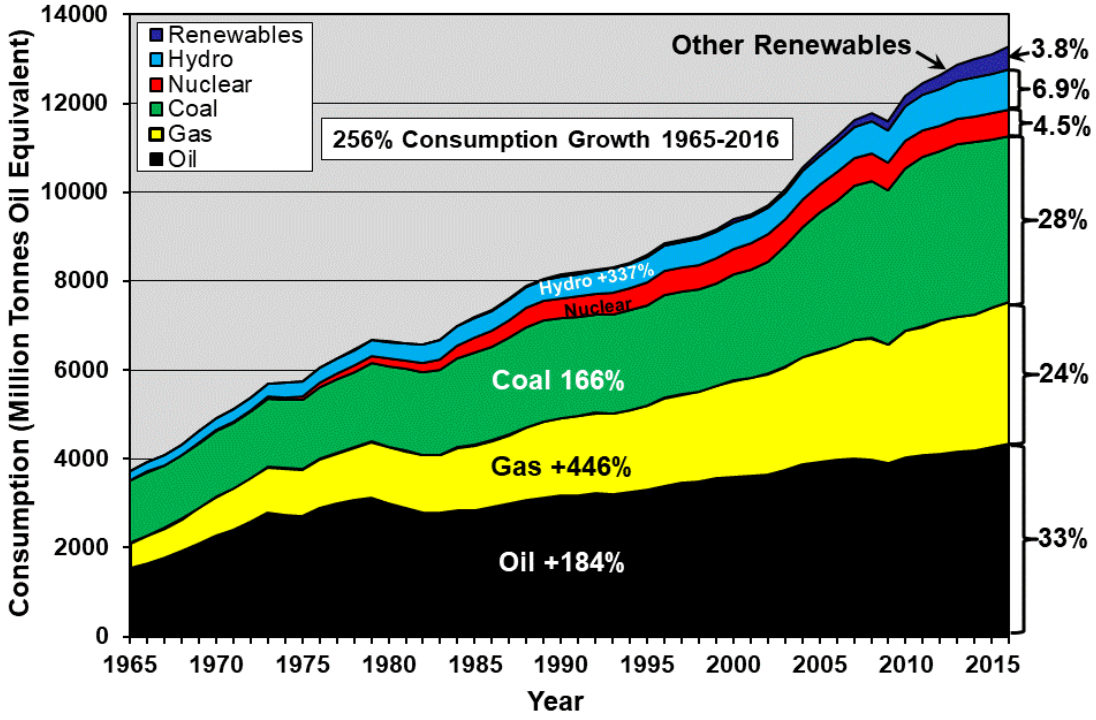


[4] Data from BP Statistical Review of World Energy, 2017

1.1.1 Trends in consumption

Energy consumption has grown rapidly in tandem with population growth and growth in per capita consumption. Globally, energy consumption has increased by more than three-fold in the past 50 years (see Figure 4). Notwithstanding the exponential growth in non-hydro renewable energy, which, along with nuclear energy and hydropower, provided 15.2% of the 2016 total, fossil fuel use tripled over this period and now provides 85% of primary energy consumption. Natural gas consumption grew more than five-fold while oil and coal nearly tripled. This suggests that even with rapid growth in renewable energy sources like wind and solar, the world will remain highly dependent on non-renewable fossil fuels for many years into the future.

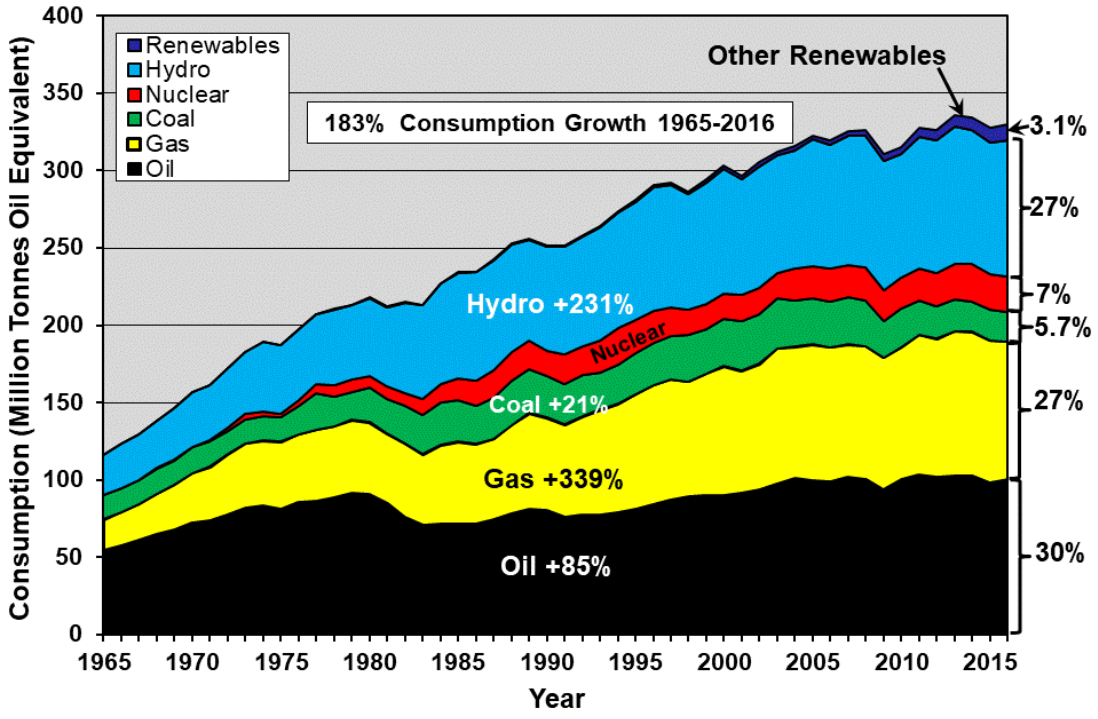
Figure 4: World primary energy consumption by fuel from 1965 to 2016.
Fossil fuels comprised 85% of 2016 consumption. "Other Renewables" include wind, solar, biomass, geothermal and biofuels. [5]



[5] BP Statistical Review, 2017

Canadian consumption over the same 50-year period increased by 183%, or nearly triple, and fossil fuels comprised 63% of the total in 2016 (see Figure 5). Natural gas consumption grew more than four-fold and oil nearly doubled. Coal consumption increased by 37% overall, but has declined substantially in recent years with the coal phase-out in Ontario. Non-hydro renewables, which include solar, wind, biomass and biofuels, contributed just 3.1% of 2016 consumption. Notwithstanding the need to reduce carbon emissions, fossil fuels, particularly oil and gas, are likely to be a significant part of Canada's energy mix for many years to come.

Figure 5: Canada primary energy consumption by fuel from 1965 to 2016.
Fossil fuels comprised 63% of the total in 2016. Oil and gas, at 57% of 2016 consumption, are equal to the world average, except that Canada uses a higher proportion of natural gas and a lower proportion of oil. "Other Renewables" include wind, solar, biomass, geothermal and biofuels. [6]

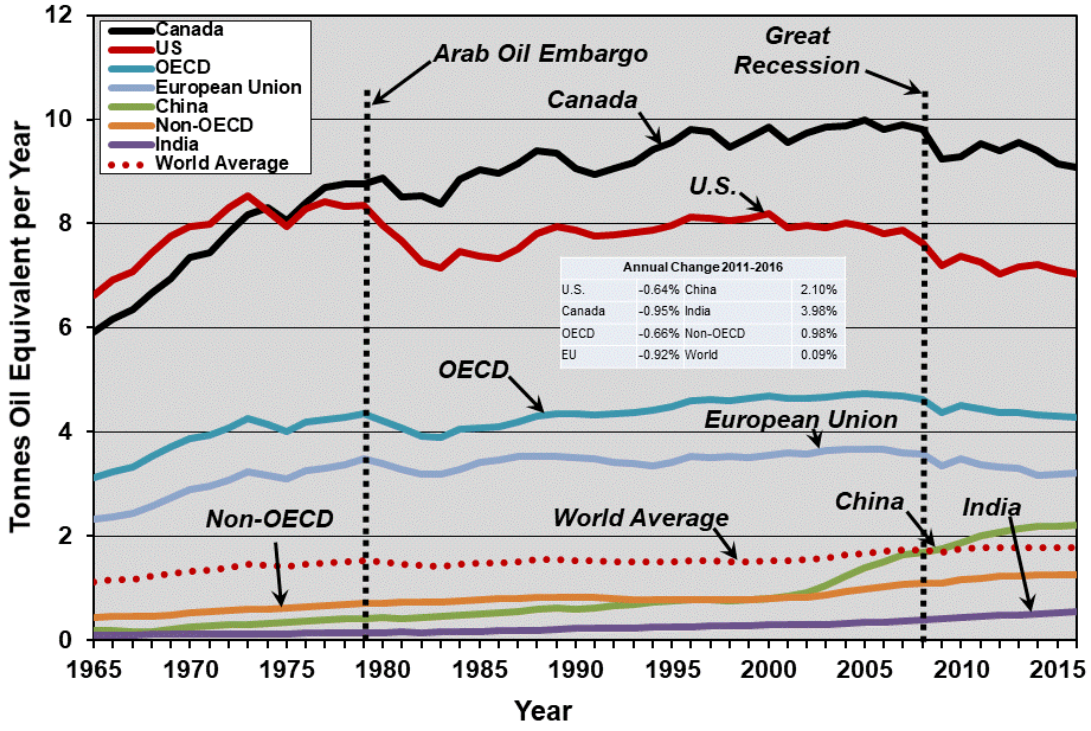


[6] BP Statistical Review, 2017

Figure 6 illustrates the change in per capita consumption of energy in Canada and other countries over the past 50 years. Canadian consumption has been one of the world's highest over this period at more than double the average of developed nations in the OECD and European Union, and five times the world average. Although Canadian consumption on a per capita basis has grown 54% since 1965, it has been declining over the past five years at an average rate of .95% per year. Similarly, other developed countries are also declining: the OECD at .66% per year, the US at .64% per year and the European Union at .92% per year. The impact of oil supply restrictions on per capita consumption during the Arab Oil Embargo beginning in 1979 and the Great Recession of 2008, which mainly affected the developed world, are also shown in Figure 6.

In contrast to the slight decline in per capita energy consumption in the developed world, the developing world is growing at high rates. Non-OECD countries, comprising 83% of the world's population, have grown.98% per year over the past five years. China has grown 2.1% per year and now exceeds the world average. India has grown 3.98% per year while the world as a whole has increased .09% per year.

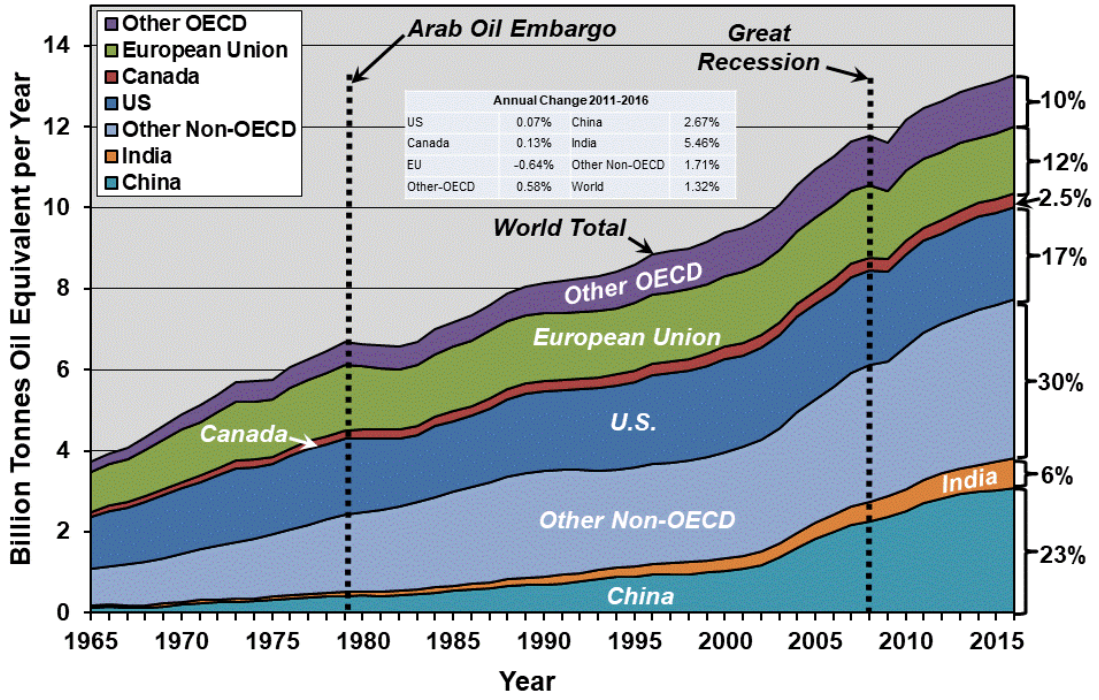
Figure 6: Per capita primary energy consumption by country from 1965 to 2016.
Developed countries far exceed the consumption levels of developing countries. Developing countries, however, are growing quickly in contrast to developed countries, which are in slight decline. The Arab Oil Embargo and Great Recession, which impacted per capita consumption in developed countries, are also shown.[7]



[7] Data from BP Statistical Review 2017 and World Bank population statistics

Total energy consumption by country over the past 50 years is illustrated in Figure 7. Total consumption growth rates are higher than those for per capita consumption, as they reflect both changes in per capita consumption and population growth. The developing world (represented by non-OECD countries), with 83% of world population, consumed as recently as 2005 less than half of the world's energy, but now consumes 59% and has grown at 1.71% per year over the past five years. China alone consumes nearly a quarter of the world's energy (for comparison, the US consumes 17%), and has grown 2.67% per year over this period. Canada consumed 2.5% of the world's energy in 2016, and has increased at .13% per year over the past five years. The developed world outside of Canada, the US and the European Union has increased its consumption by .58% per year, while the European Union has been declining at .64% per year over this period. Energy consumption in the world as a whole has increased 1.32% per year over the past five years.

Figure 7: Total energy consumption by country from 1965 to 2016.
Developing countries, which comprise 83% of world population, have increased consumption rapidly and now account for 59% of world consumption. Developing countries also have far higher consumption growth rates than the developed world. Total world energy demand has grown at an average 1.32% per year over the past five years. Although growth has slowed in developed nations (and has declined in the European Union), it continues to grow at rates of nearly 3% per year in China and over 5% per year in India. [8]



Given world growth rates and forecasts of continued population growth, it is clear that the world will demand more and more energy over the coming years, much of it from fossil fuels. Whether supply can meet demand is another matter, given the fact that fossil fuels are finite, non-renewable resources. Although it is generally accepted that there are far more fossil fuel resources than humanity can afford to burn given climate change, they are increasingly found in lower-quality deposits that are more difficult to access for economic, environmental and geopolitical reasons.

[8] Data from BP Statistical Review 2017

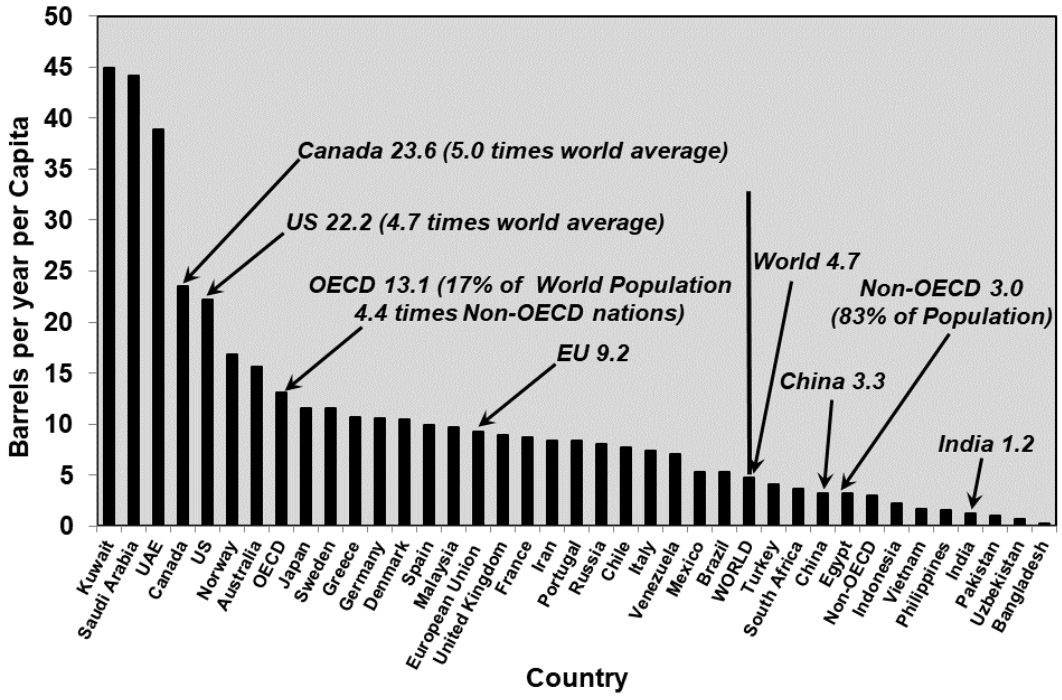
1.1.2 Trends in consumption by fuel

The following section examines consumption trends for all energy inputs into the Canadian energy system, in relationship to other countries, in order to assess their relative importance and potential contribution in the future.

1.1.2.1 OIL

Oil is the number one energy input into both the world and Canadian economies, and is the premier fuel for transportation. Figure 8 illustrates per capita consumption by country in 2016. Canada is among the highest oil consuming countries in the world, at 23.6 barrels per person per year, which is 6% more than the average American and five times the world average. There is a great inequity in oil consumption between the developed and developing worlds, with OECD countries, which represent just 17% of world population, consuming 4.4 times as much oil as non-OECD countries. Canadians consume seven times as much oil as the average person in China and 19 times the average person in India. Industrialized countries like Germany and other countries in the European Union consume per capita less than half the oil of Canadians.

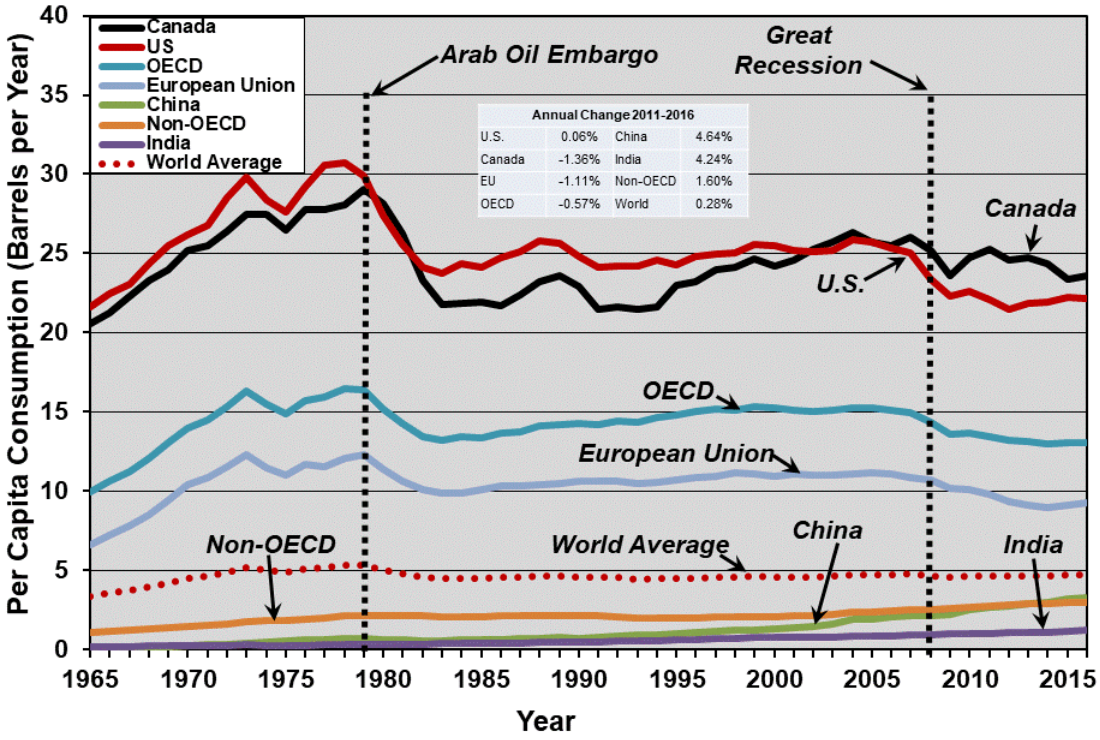
Figure 8: Per capita oil consumption by country in 2016.
Canadians are among the highest consumers in the world at five times the world average.[9]



[9] Data from BP Statistical Review 2017 and World Bank population statistics for 2016

Figure 9 illustrates trends in per capita oil consumption over the past 50 years for Canada and other countries. Per capita consumption in most developed countries and in the world as a whole peaked in 1979 at the time of the Arab Oil Embargo. Although consumption grew slowly again in the 1980s and 1990s, it has been declining in the developed world over the last five years (with the exception of the US), primarily as a result of the Great Recession that began in 2008. In contrast, per capita oil consumption in the developing world has grown rapidly in recent years, offsetting declines in the developed world, such that the world as a whole has been growing at an average annual rate of .28% over the past five years.

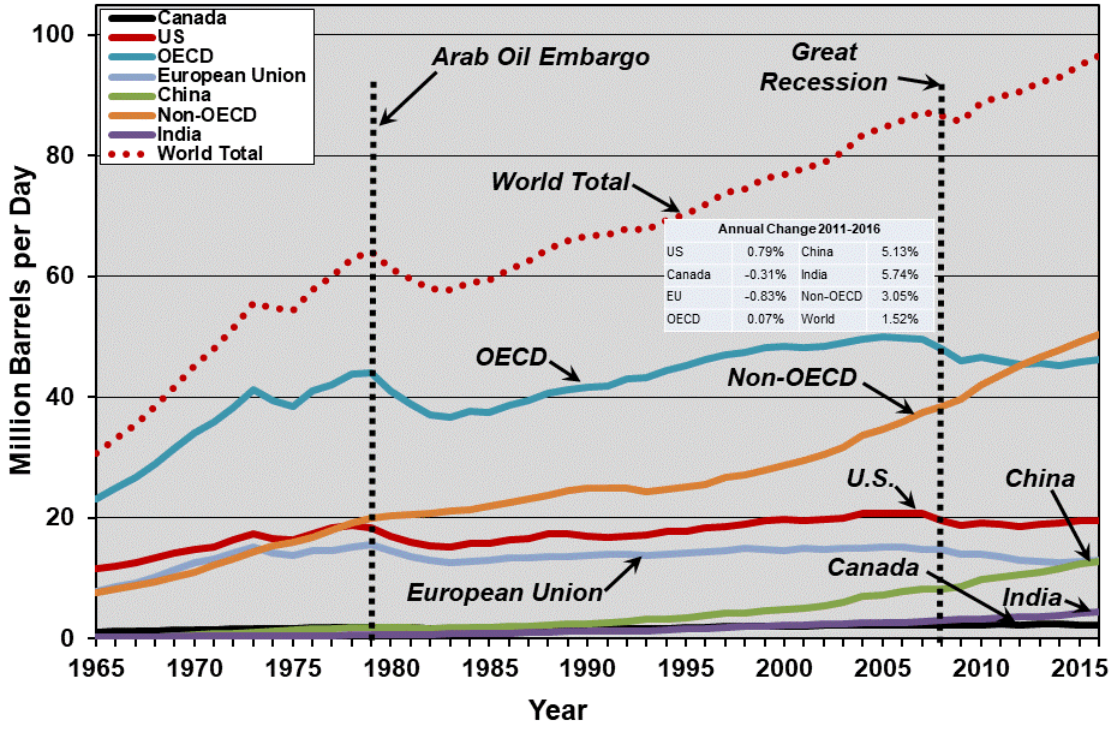
Figure 9: Per capita oil consumption by country from 1965 to 2016.
Consumption peaked in 1979 overall and, with the exception of the US, has been declining recently in the developed world. Rapid consumption growth in the developing world has, however, offset these declines, and the world as a whole has been slowly increasing its per capita oil consumption over the past five years.[10]



[10] Data from BP Statistical Review 2017 and World Bank population statistics for 2016

Figure 10 illustrates total oil consumption by country over the past 50 years. Given population growth, consumption has been increasing globally at an average rate of 1.52% per year over the past five years. Although oil consumption growth has been almost flat in developed OECD countries (.07% per year increase), and declining in the European Union and Canada (.83% and .31% per year decreases, respectively), it has been growing rapidly in the developing world, with non-OECD countries up an average of 3.05% per year, and China and India up 5.13% and 5.74% per year, respectively. Non-OECD countries now consume more oil than OECD countries.

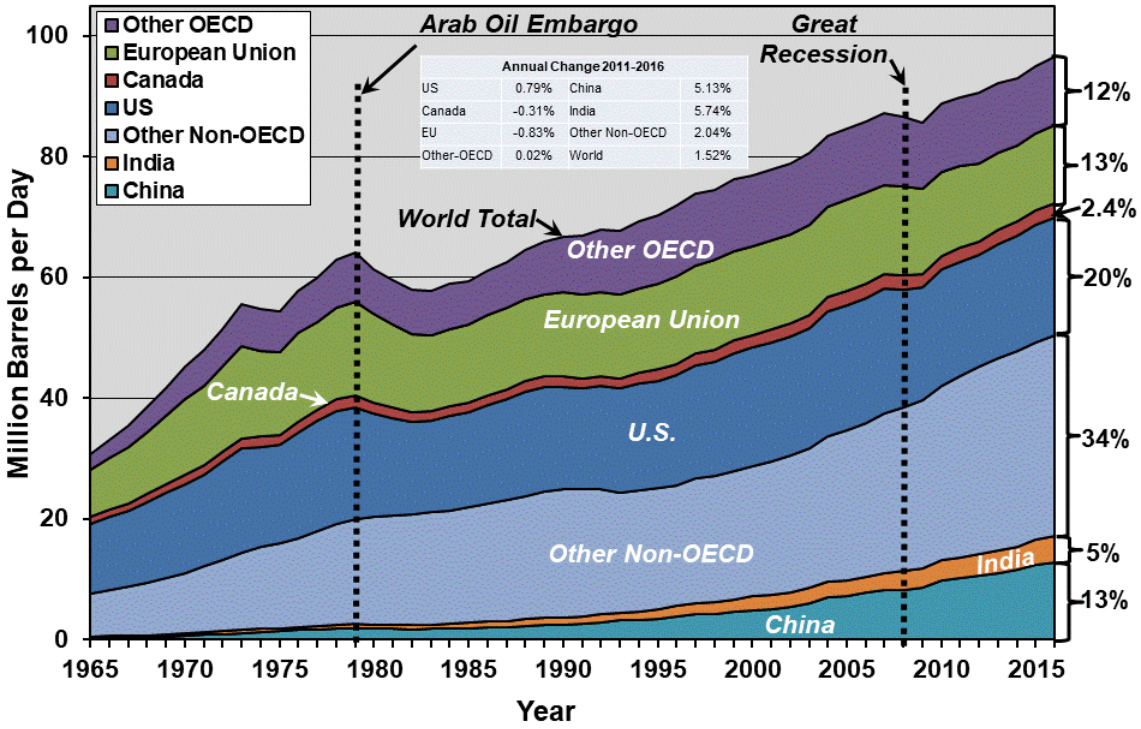
Figure 10: Total oil consumption by country from 1965 to 2016.
World consumption has grown at 1.52% per year over the past five years. Consumption is flat in developed (OECD) countries but is growing rapidly in developing (non-OECD) countries. Non-OECD countries now consume more oil in total than OECD countries.[11]



[11] Data from BP Statistical Review 2017

Figure 11 shows a stacked chart of total oil consumption by country over the past 50 years. Most future growth in oil consumption is likely to come from developing countries, which are growing from low per capita consumption levels. Oil consumption in the developed world is already very high on a per capita basis and hence oil prices tend to have a proportionately larger impact on dampening consumption there than in the developing world. Notwithstanding its high per capita consumption, Canada accounts for just 2.4% of global oil consumption, given its relatively small population.

Figure 11: Total oil consumption by country from 1965 to 2016.
The developing world represented by non-OECD countries is growing rapidly, more than offsetting declines in most of the developed world.[12]



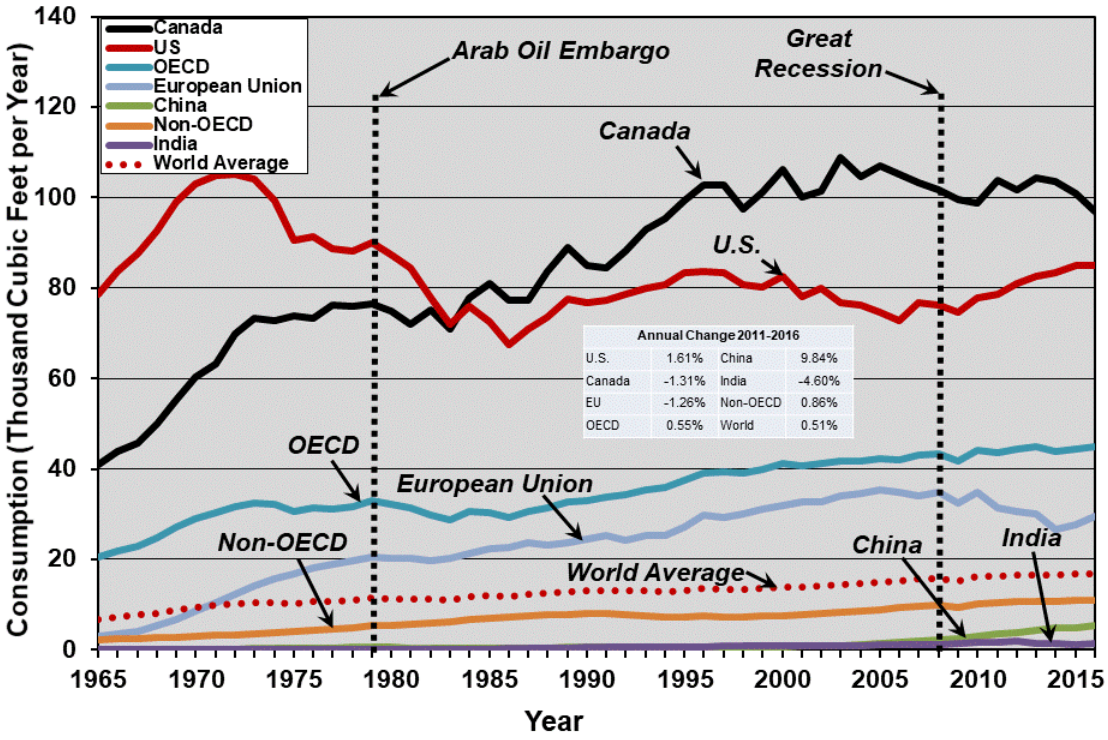
1.1.2.2 NATURAL GAS

Natural gas is the third-largest energy source globally and the second-largest source in Canada. It is the fastest growing fossil fuel, having increased more than four-fold globally over the past 50 years. As with oil, Canada is one of the highest per capita consumers of gas in the world, at 5.8 times the world average in 2016, when Canadian consumption was 14% higher than US consumption. Canadians consumed 18 times as much natural gas as the average person in China and 73 times that of the average person in India in 2016. Industrialized countries represented by the OECD consume on average less than half the natural gas of Canada per capita, and countries in the European Union consume less than a third.

[12] Data from BP Statistical Review 2017

Figure 12 illustrates trends in per capita consumption by country over the past 50 years. Natural gas consumption in the world as a whole has been growing more slowly than oil on a per capita basis over the past five years, at .51% per year. Natural gas consumption in the industrialized countries represented by the OECD, however, grew faster than oil consumption over this period (.55% per year), but in developing countries grew more slowly (.86% per year for gas versus 1.6% per year for oil). Per capita consumption of natural gas in Canada and the European Union fell over this period, at 1.31% and 1.26% per year, respectively. US per capita consumption peaked in 1972, although it has been growing at 1.61% per year over the past five years due to the shale revolution and the switch from coal to gas for electricity generation. China has grown very rapidly over the past five years, at 9.84% per year, but this growth has been offset by India, which declined 4.6% per year over the same period.

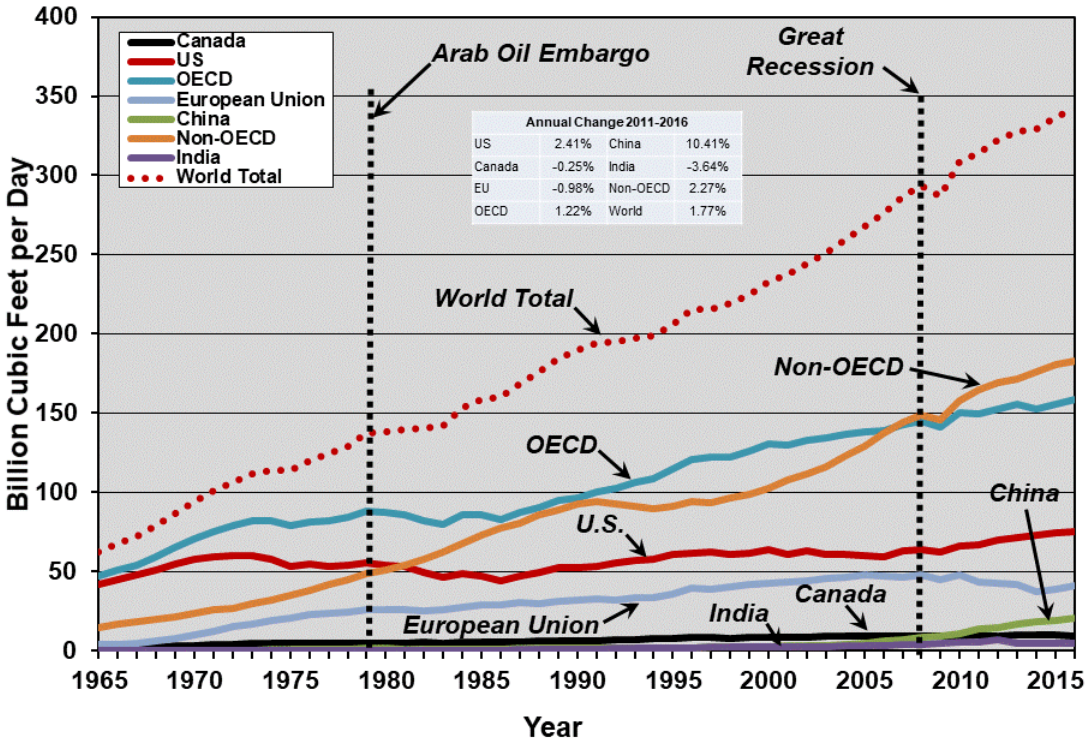
Figure 12: Per capita natural gas consumption by country from 1965 to 2016.
Although per capita consumption has been growing rapidly in China, global gas consumption has lagged oil consumption growth over the past five years.[13]



[13] Data from BP Statistical Review of World Energy, 2017

Figure 13 illustrates total natural gas consumption by country over the past 50 years. Given population growth, total consumption has been growing globally at an average rate of 1.77% per year over the past five years. Total consumption has increased in developed countries represented by the OECD at 1.22% per year over this period, and at 2.27% per year in non-OECD countries. China increased at 10.41% per year whereas India declined at 3.64% per year. The non-OECD countries now collectively consume more gas than the OECD countries. Canadian consumption over the past five years has been declining at .25% per year, and the European Union has been declining at .98% per year.

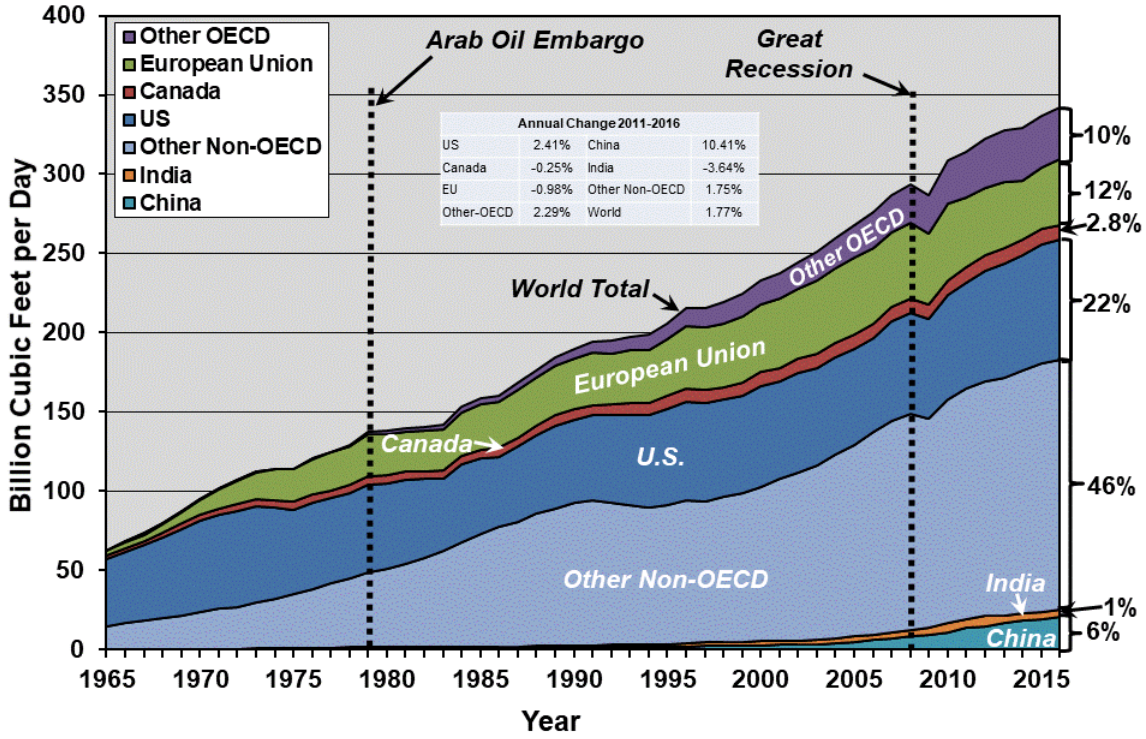
Figure 13: Total natural gas consumption by country from 1965 to 2016.
Consumption has increased in developed (OECD) countries but has grown much more rapidly in developing (non-OECD) countries. Non-OECD countries now consume more natural gas in total than OECD countries.[14]



[14] Data from BP Statistical Review 2017

Figure 14 shows a stacked chart of total gas consumption by country over the past 50 years, illustrating the proportions of gas consumed. As with oil, consumption of natural gas in the developed world is already very high on a per capita basis, and although there is scope for some further growth given the shift from coal for electricity, far more growth will occur in the developing world. Notwithstanding its per capita consumption of gas, which is among the highest in the world, Canada accounts for just 2.8% of total global gas consumption, given its relatively small population.

Figure 14: Total natural gas consumption by country from 1965 to 2016.
The developing world represented by non-OECD countries is growing rapidly and natural gas has been by far the highest-growth fossil fuel over the past 50 years.[15]



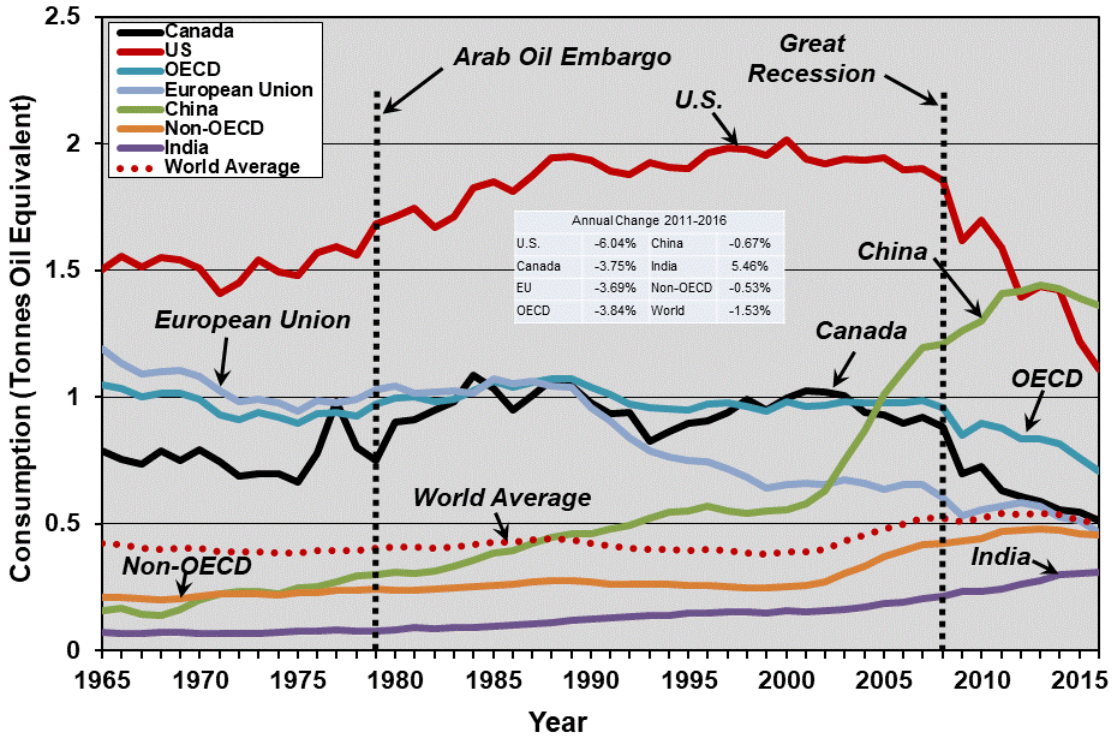
1.1.2.3 COAL

Coal is the second-largest energy source globally and the fifth-largest in Canada. Coal use has been falling rapidly in the industrialized world and growing slowly in the developing world, with world coal consumption peaking in 2014 and falling 4.4% since then. Although US consumption has been falling rapidly in recent years, in 2016 the US still consumed on a per capita basis 81% as much coal as China, which is the largest consumer of coal in the world. On a per capita basis, Canadians consume 54% less coal than Americans but 2% more than the world average. Coal is a major component of electricity generation in Alberta, Saskatchewan and Nova Scotia, but most domestic use will be phased out by 2030 under current climate legislation.

[15] Data from BP Statistical Review 2017

Figure 15 illustrates trends in per capita coal consumption by country over the past 50 years. Over the past five years, coal use on a per capita basis has fallen at 1.53% per year globally, 3.84% per year in OECD countries and .53% per year in non-OECD countries. India is an exception—per capita coal use has been growing there at 5.46% per year over this period. China consumes half of the world's coal production. Although per capita consumption of coal in China has more than doubled since 2000, it has declined at .67% per year over the past five years. On a per capita basis, US consumption of coal peaked in 2000 and Canadian consumption peaked in 1984.

Figure 15: Per capita coal consumption by country from 1965 to 2016.
Per capita consumption has fallen rapidly in the developed world over the past five years and at 1.53% per year globally.[16]

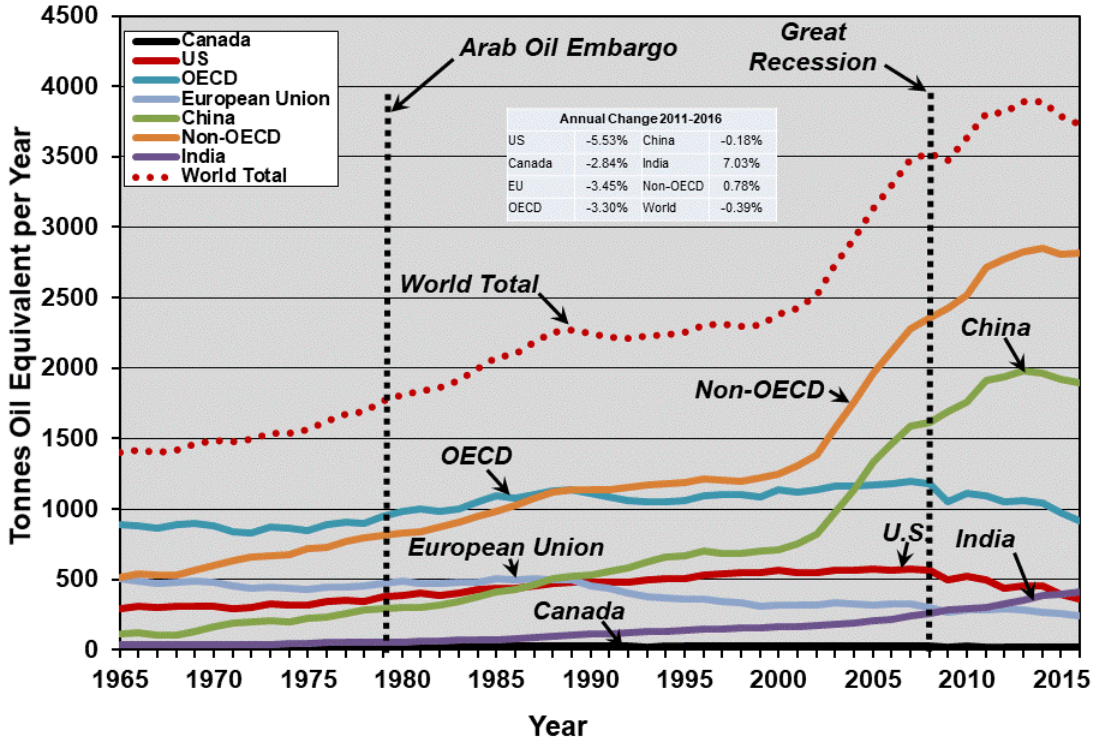


[16] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 16 illustrates total coal consumption by country over the past 50 years. Although total consumption has nearly tripled since 1965, consumption over the past five years has been declining globally at an average rate of .39% per year, declining at 3.3% per year in OECD countries and growing at .78% per year in non-OECD countries. Coal consumption in the world as a whole has increased by 56% since 2000, mostly due to growth in India and China. Canada and the US have decreased coal consumption by 2.84% and 5.53% per year, respectively, over the past five years.

Figure 16: Total coal consumption by country from 1965 to 2016.

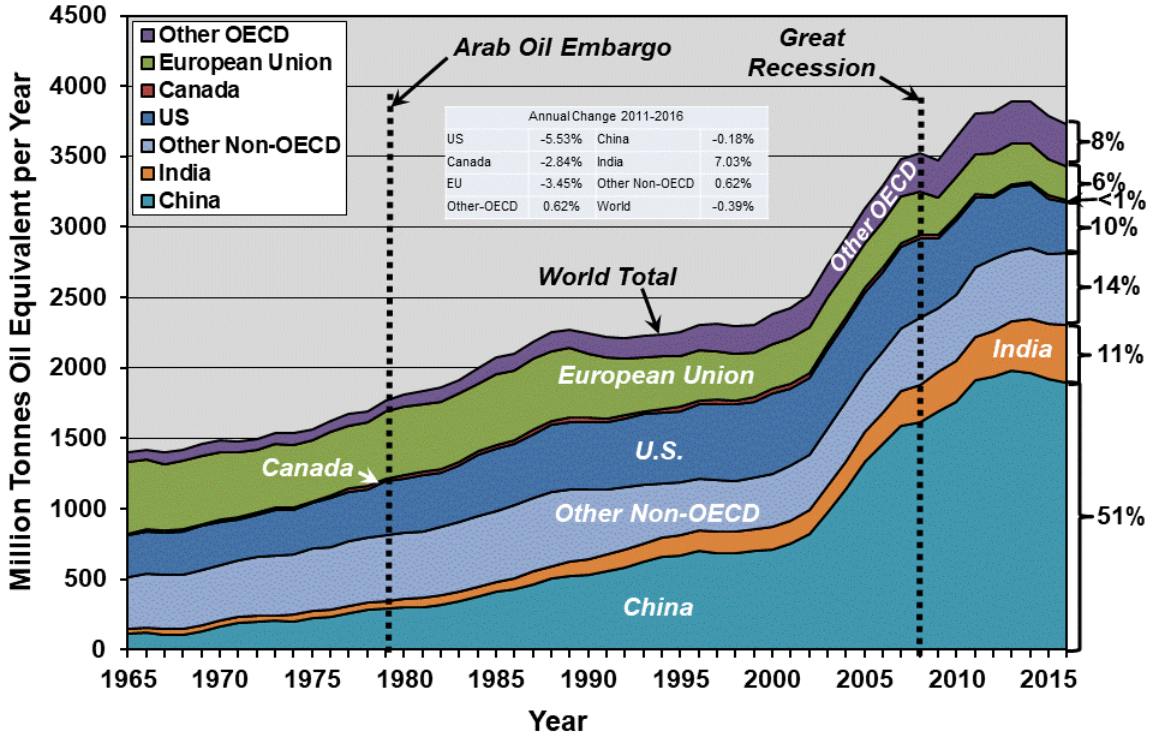
Consumption has declined rapidly over the past five years in developed (OECD) countries, but it continues to grow in developing (non-OECD) countries. Non-OECD countries now consume nearly three-quarters of the world's coal production.[17]



[17] Data from BP Statistical Review 2017

Figure 17 shows a stacked chart of total coal consumption by country over the past 50 years, illustrating the proportions of coal consumed. Future growth in coal consumption, if any, is likely to be confined mainly to the developing world, given concerns with greenhouse gas emissions and the ability of natural gas and renewables to replace coal for electricity generation. However, coal will remain a major input into the steel-making industry (Canada is a major exporter of metallurgical coal). Canada accounted for just .51% of current global coal consumption in 2016, given its abundant hydro resources and relatively small population. As the second-largest source of energy in the world, coal will be a significant challenge to replace.

Figure 17: Total coal consumption by country from 1965 to 2016.
Coal consumption peaked globally in 2014, although it continues to grow in developing (non-OECD) countries, which now consume 76% of all coal production, with China alone consuming half.[18]



1.1.2.4 NUCLEAR

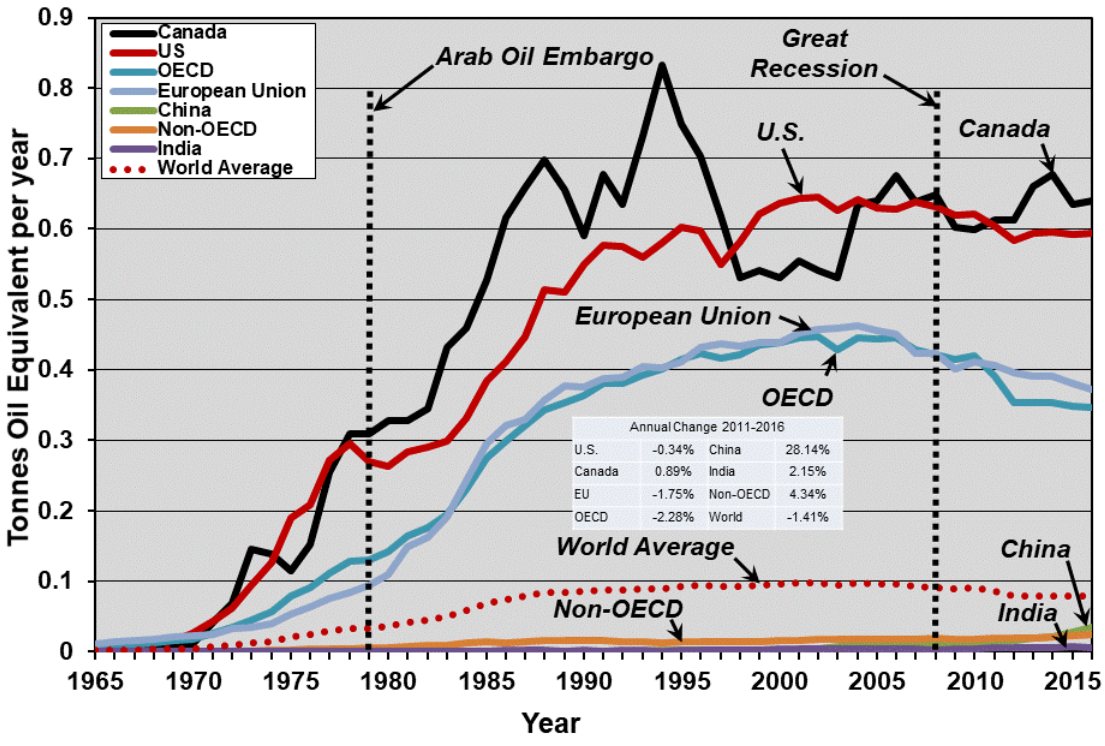
Nuclear is the fifth-largest energy source globally and the fourth-largest in Canada. Nuclear power generation peaked globally in 2006 and has declined 7% as of 2016. Nuclear use has been falling in the industrialized world as a result of reactor shutdowns following the Fukushima accident in Japan, and an aging nuclear reactor fleet requiring the decommissioning of the oldest units. Nuclear energy is predominantly generated in the industrialized world, with OECD countries accounting for 75% of total generation, but it is growing rapidly in the developing world, particularly China. The US and the European Union together generated two-thirds of global nuclear power in 2016. Canada is a major consumer of nuclear energy—consuming more than the US and the European Union on a per capita basis. Canadian nuclear generation has been growing in the last few years with the refurbishment of some plants in Ontario and New Brunswick, although peak production occurred in 1994 when the Darlington plant came online and it has declined slightly since then (4%). Canadian mines supplied about 16% of the world's

[18] Data from BP Statistical Review 2017

uranium in 2014 and Canada has 9% of the world's identified recoverable uranium resources. Canadian reactors burned about 3.3% of the world's uranium supply in 2015.[19]

Figure 18 illustrates trends in per capita nuclear energy consumption by country over the past 50 years. Globally, per capita consumption peaked in 2002 and has fallen by 18% as of 2016. There were 447 operable reactors in the world and 56 under construction as of August 2017.[20] China alone has 20 reactors under construction, followed by Russia with seven, India with six and the US with two (two construction projects in the US were shut down in July 2017). Many existing reactors will be coming offline over the next 10 to 15 years, having reached their design lifetimes, hence it is expected that new reactors under construction will just maintain, not significantly increase, global nuclear generation. Some 66 reactors were retired between 1996 and 2013, and the rate of retirements will increase in the future owing to the age of the existing fleet. There are an additional 162 "planned" and 349 "proposed" nuclear reactors globally, but how many of these will be built is questionable given capital costs and anti-nuclear sentiment in the wake of the Fukushima disaster. In Canada, there are 19 operating reactors, none under construction and two listed as "planned." Canada's nuclear fleet is aging and there will be more retirements over the coming years (Canada's nuclear industry is discussed in more detail in a later section).

Figure 18: Per capita nuclear energy consumption by country from 1965 to 2016.
Per capita consumption peaked in Canada in 1994 and in the world as a whole in 2002. Although nuclear energy consumption is falling in the industrialized world, it is growing rapidly in the developing world, particularly in China.[21]



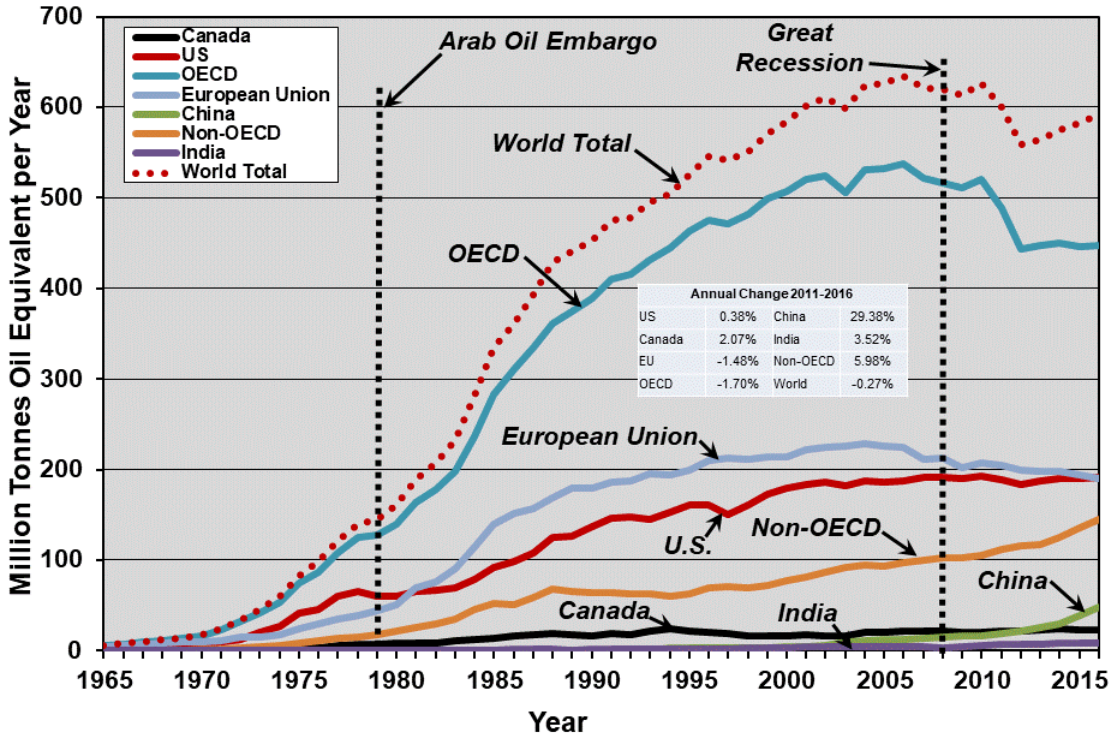
[19] Joint Report by the OECD Nuclear Energy Agency and the International Atomic Energy Agency, 2016, Uranium 2016: Resources, Production and Demand, https://www.oecd-nea.org/ndd/pubs/2016/7301-uranium-2016.pdf

[20] World Nuclear Association, August 2017, World Nuclear Power Reactors and Uranium Requirements, http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/ Note that two US reactor construction projects were shut down in late July, 2017, which reduces the actual number under construction to 56, rather than 58 as noted in this reference.

[21] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 19 illustrates total nuclear energy consumption by country over the past 50 years. Global nuclear generation has declined slightly (.27% per year) over the past five years and has grown since 2013 after a sharp drop following the Fukushima disaster. Developed (OECD) countries collectively declined at 1.7% per year over the past five years, although Canada (2.07% per year) and the US (.38% per year) grew slightly. The developing world is the main catalyst for future nuclear generation growth, with non-OECD countries increasing at 6% per year over the past five years and China averaging a 29% per year increase.

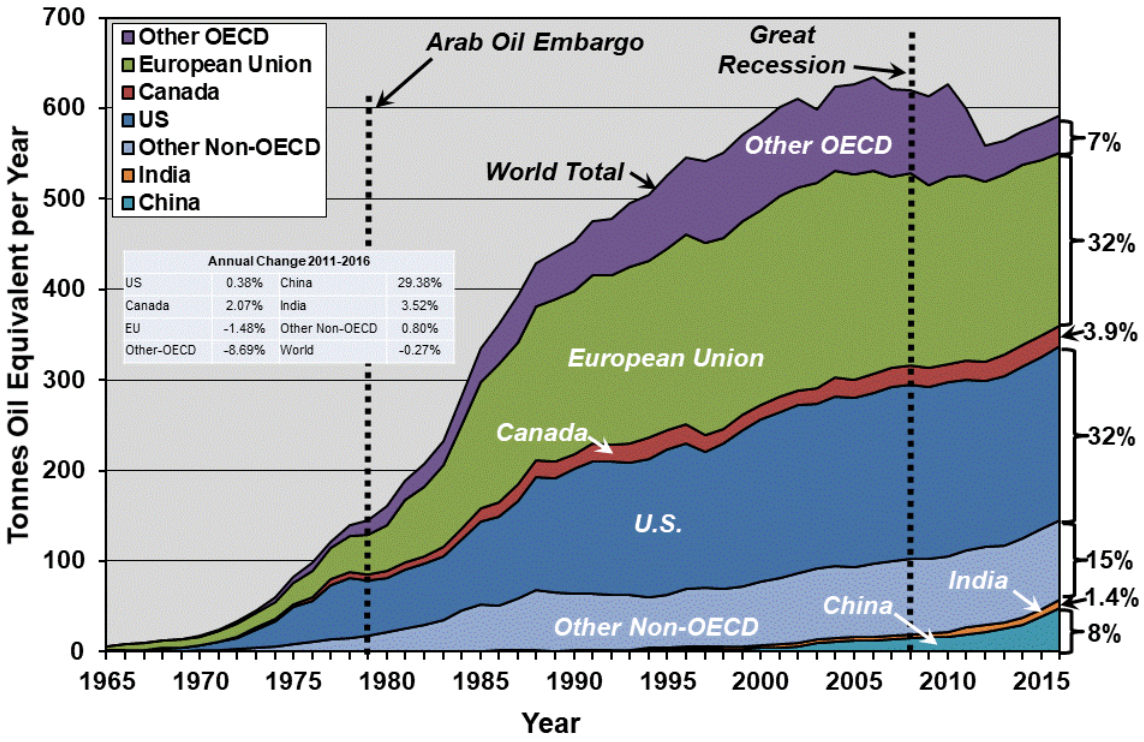
Figure 19: Total nuclear energy consumption by country from 1965 to 2016.
Consumption has declined in developed countries (represented by the OECD) and grown rapidly in developing (non-OECD) countries, although non-OECD countries still consume a small proportion of global nuclear energy. Canadian consumption has grown somewhat in the last five years with the refurbishment of some reactors.[22]



[22] Data from BP Statistical Review 2017

Figure 20 shows a stacked chart of total nuclear generation by country over the past 50 years, illustrating the proportions of nuclear energy consumed. Nuclear energy is predominantly a developed-world energy source, although it is growing rapidly in the developing world. The shutdown of reactors in Japan after the Fukushima disaster is the main cause of the post-2011 decline in global nuclear generation. The planned shutdown of reactors in Germany by 2022 will further stall global growth. Canada generated 3.9% of the world's nuclear power in 2016.

Figure 20: Total nuclear consumption by country from 1965 to 2016.
The developed world represented by OECD countries is by far the largest consumer of nuclear energy at 75% of 2016 generation, but the developing world, in particular China, is growing fast.[23]



1.1.2.5 HYDRO

Hydropower from large facilities is the fourth-largest energy source globally and the third-largest in Canada. Although hydropower production has been relatively flat in the industrialized world over the past two decades, it is growing rapidly in the developing world. Since 2000, developing (non-OECD) countries have produced more hydropower than OECD countries, and now produce two-thirds of the world's hydropower.

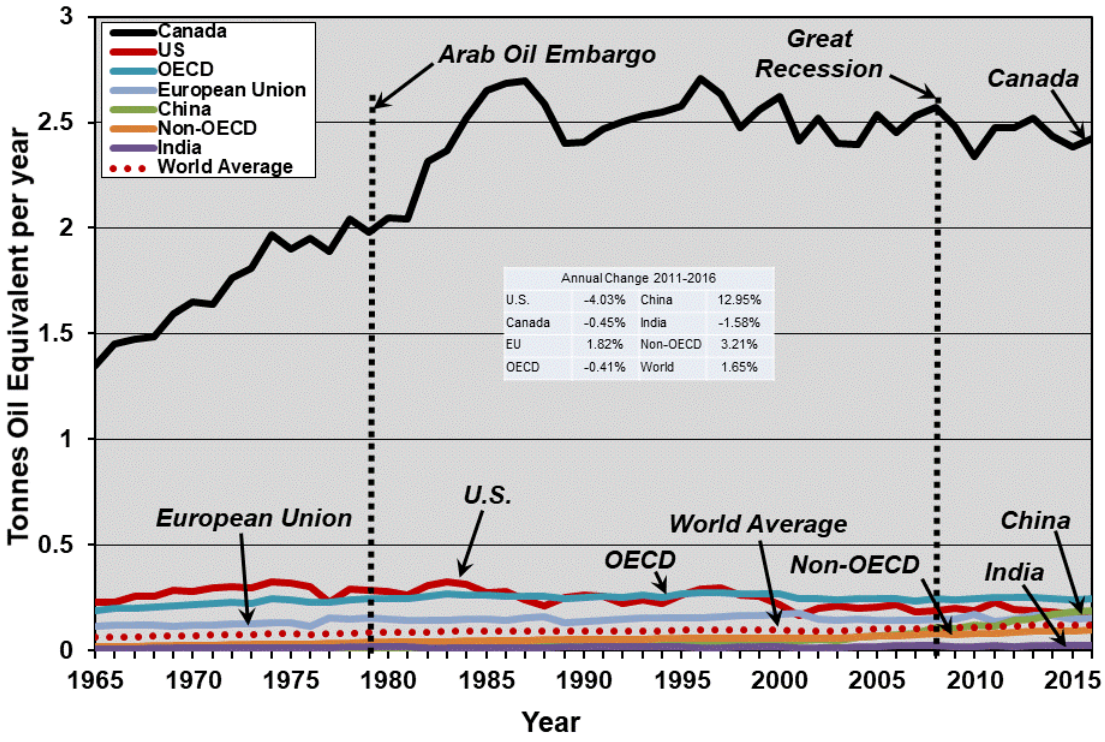
Canada has vast hydropower resources compared to most countries, and was the second-largest hydropower producer in the world in 2016. On an oil-equivalent basis, hydro provided 27% of Canada's primary energy in 2016, compared to 6.9% for the world as a whole. Canadians consumed on a per capita basis 20 times as much hydropower as the world average in 2016. This was exceeded only by Norwegians, who consumed 51 times the world average. By contrast, Americans consumed 1.5 times the world average and, despite the development of the massive Three Gorges Dam and being the world's largest hydropower

[23] Data from BP Statistical Review 2017

producer, the Chinese consumed just 1.6 times the world average. On an oil-equivalent basis, hydropower provided 2.6% and 8.6% of total primary energy consumption in the US and China in 2016, respectively.

Figure 21 illustrates trends in per capita hydropower consumption by country over the past 50 years. Hydro has been increasing globally at 1.65% per year over the past five years. This growth is mainly in the developing world, with an average increase of 3.21% per year in non-OECD countries, compared to a decline of 0.41% per year in OECD countries. Canadian consumption of hydro grew very rapidly from the mid-1960s to the 1980s with the completion of large dams in BC, Manitoba, Ontario and Quebec. Per capita consumption in Canada has been falling over the past five years given the slow rate of increase in the completion of major new hydro projects and the increase in Canadian population.

Figure 21: Per capita hydropower consumption by country from 1965 to 2016.
Per capita consumption has been declining in the developed world (represented by OECD countries) over the past five years, but has been growing rapidly in the developing world, particularly China.[24]

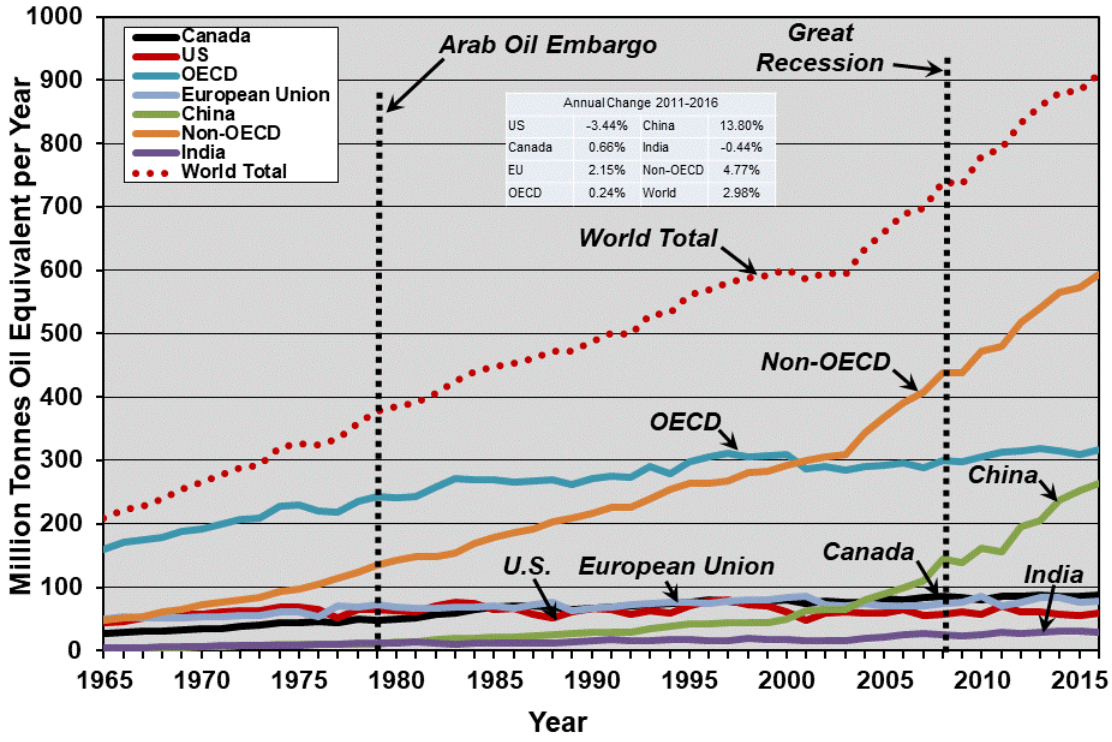


[24] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 22 illustrates total hydropower consumption by country over the past 50 years. Given population growth, consumption has been growing globally at an average rate of 2.98% per year over the past five years, and hydropower consumption in the world as a whole has increased by 87% since 1990. In developing (non-OECD) countries, hydropower consumption has grown by 175% since 1990. It has increased more than nine-fold in China, compared to growth of just 17% in OECD countries and a decline of 10% in the US Hydropower has increased by 31% in Canada since 1990 (as of 2016).

Figure 22: Total hydro consumption by country from 1965 to 2016.

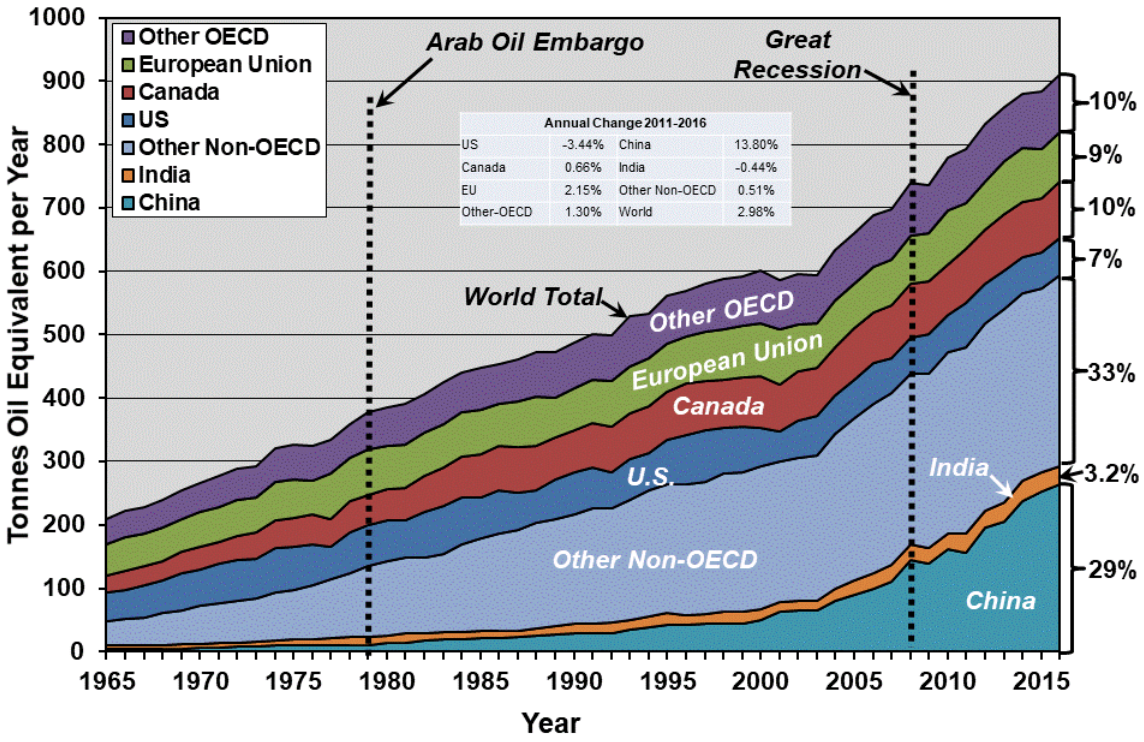
Consumption has been flat in developed (OECD) countries since 1995, compared to strong growth in non-OECD countries.[25]



[25] Data from BP Statistical Review 2017

Figure 23 shows a stacked chart of total hydro consumption by country over the past 50 years, illustrating the proportions of hydro consumed. The developing world consumed 65% of global hydropower output in 2016. The importance of hydro to Canada can be seen in the fact that it produced 10% of total global hydropower and 28% of OECD hydropower in 2016. Future growth in hydropower is likely to be confined mainly to the developing world. Although there are still some sites remaining in the developed world, particularly in Canada, decommissioning of dams has begun in the US, and there is a growing amount of public opposition to major new projects given their environmental impacts.

Figure 23: Total hydro consumption by country from 1965 to 2016.
The developing world (represented by non-OECD countries) is growing rapidly and now consumes 65% of all hydro production, with China alone consuming more than a quarter of global hydro output in 2016. Canada produces 10% of global hydro output yet comprises just 0.5% of the world's population.[26]



1.1.2.6 NON-HYDRO RENEWABLES

Non-hydro renewables refer to fuel sources other than hydropower that are renewable and provide electricity, heat and transport fuel. They include solar, wind, geothermal, biomass and biofuels. They do not include traditional biomass used for cooking and heating primarily in the developing world, which was estimated to account for 9.1% of global energy consumption in 2010 according to the UN's REN21.[27] The consumption of traditional biomass is not included in the charts in this report owing to the paucity of accurate consumption data. Forecasters at the UN's IRENA expect traditional biomass to be largely phased out over the next two decades.[28]

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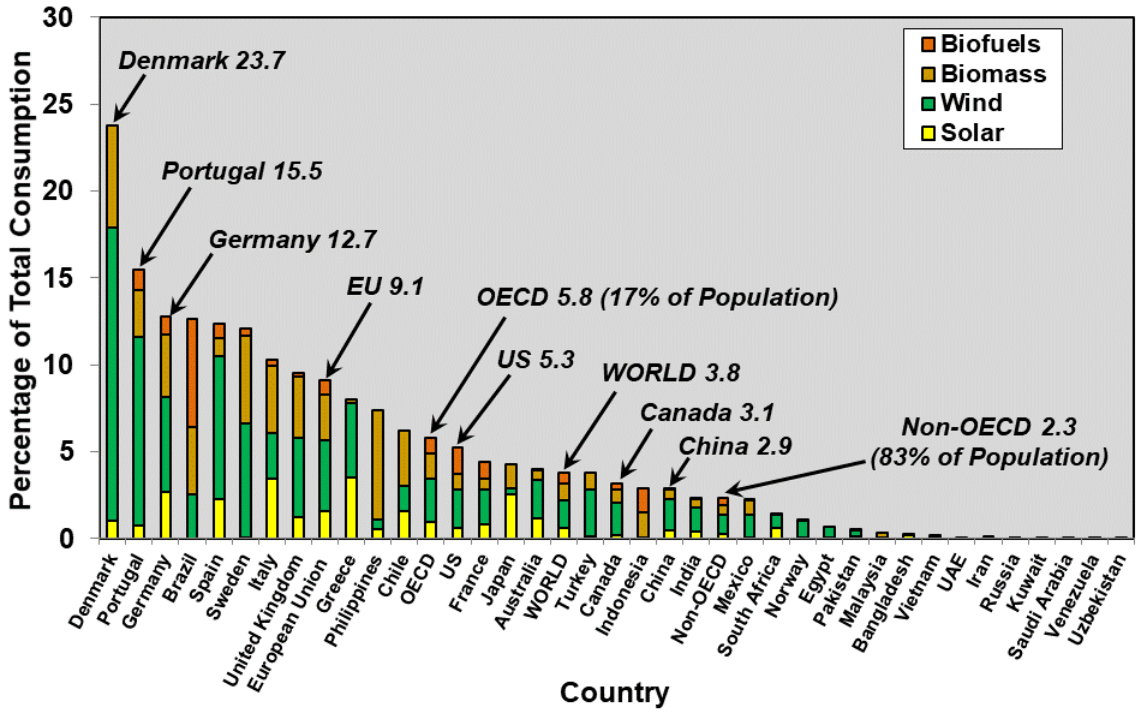
[26] Data from BP Statistical Review 2017

[27] REN21, 2017, Renewables 2017 Global Status Report, http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf

[28] UN IRENA, June 2014, Remap 2030, A Renewable Energy Roadmap, see page 23, http://www.irena.org/remap/REmap_Report_June_2014.pdf

Non-hydro renewable energy has been growing exponentially in recent years but from a very small base, such that just 3.8% of global energy consumption was from non-hydro renewables in 2016. Deployment of non-hydro renewables has been much more pervasive in the developed world than in the developing world. Figure 24 illustrates the percentage of primary energy consumption obtained from non-hydro renewables by country in 2016. Denmark obtained nearly a quarter of its primary energy from them, followed by Portugal (16%), Germany (13%), Brazil (13%) and Spain (12%). Canada, at 3.1%, is below the world average and considerably below the US which is at 5.3%.

Figure 24: Percentage of primary energy provided by non-hydro renewables by country in 2016.
Globally, 3.8% of total consumption was provided by non-hydro renewables, although Denmark obtained nearly a quarter of its primary energy from non-hydro renewables in 2016, and the European Union as a whole obtained 9.1%. Canada obtained 3.1% from non-hydro renewables in 2016.[29]

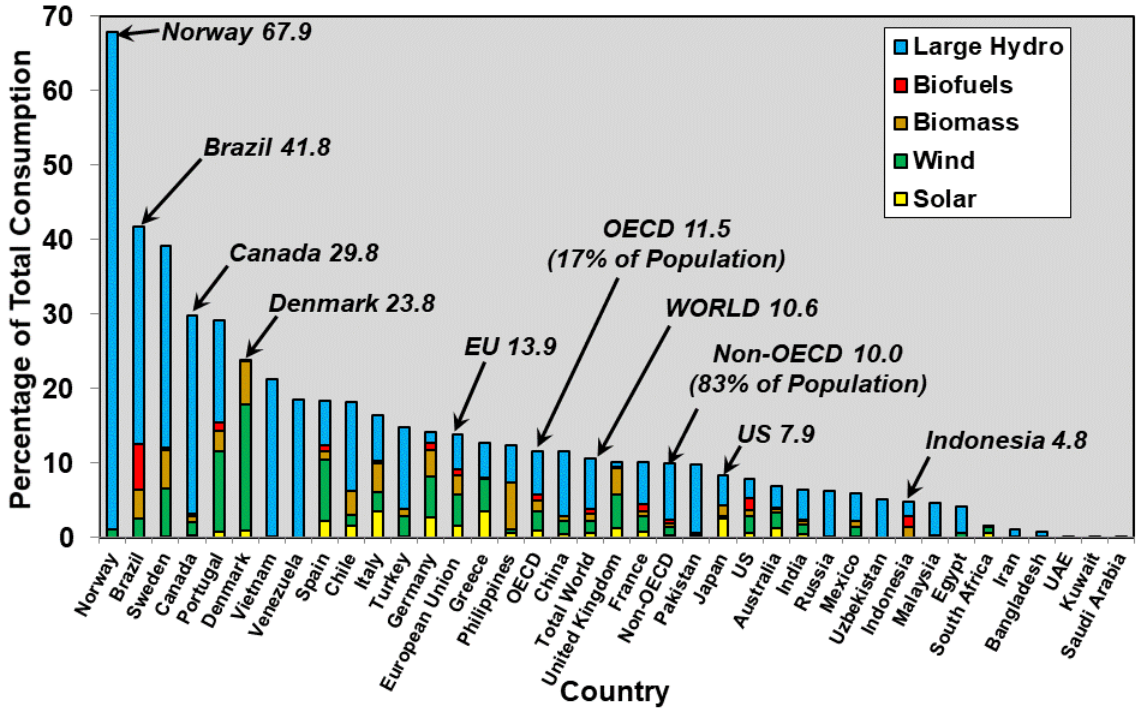


[29] Data from BP Statistical Review 2017

In terms of total renewable energy, hydropower generated twice as much primary energy in 2016 as all other forms of renewable energy combined (excluding traditional biomass). Figure 25 illustrates total renewable energy consumption including hydropower by country in 2016. In this case Denmark, the world's largest consumer of non-hydro renewable energy, ranks behind Canada, which generated 29.8% of its primary energy from renewable sources. Norway, a very small consumer of non-hydro renewable energy, obtained two-thirds of its primary energy from renewables in 2016 if hydropower is included. Large hydro projects are much more prevalent in the developing world than non-hydro renewable projects, hence when hydro is included the developing world (represented by non-OECD countries) obtained nearly as much primary energy (10%) from renewables as the developed countries (11.5%) in 2016.

Figure 25: Percentage of primary energy by country provided by all forms of renewable energy (including hydro) in 2016.

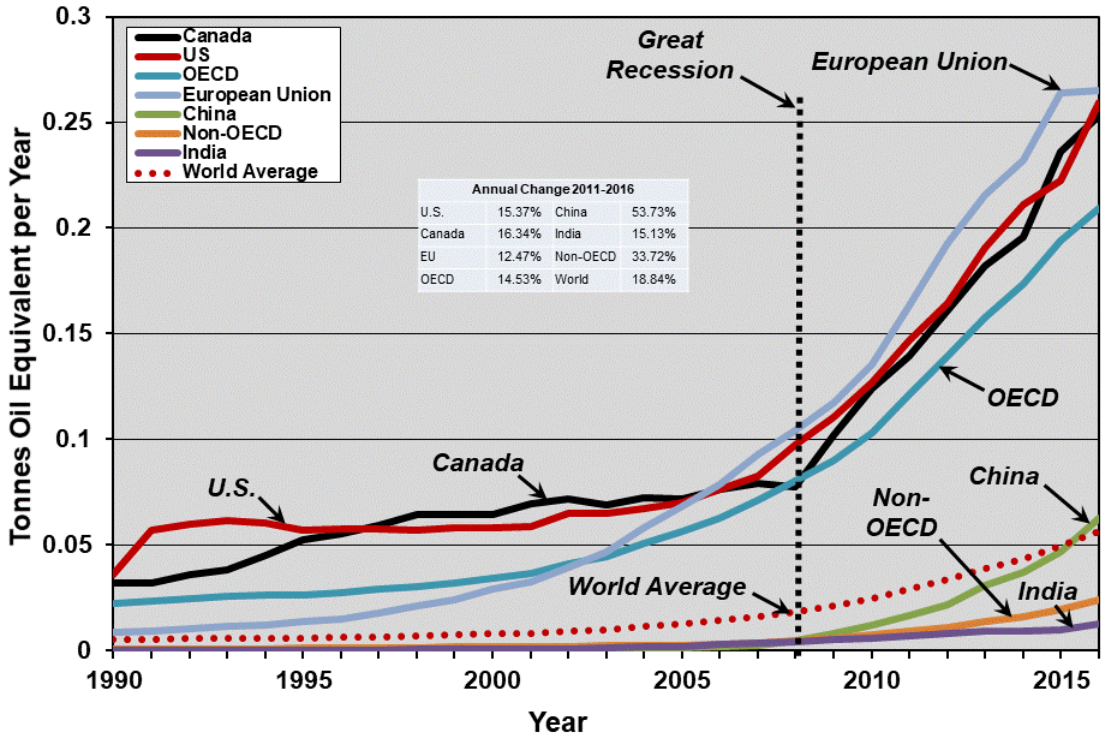
Globally, 10.6% was provided by renewables, and Canada obtained nearly 30% of its primary energy from renewables thanks to its large hydropower resource.[30]



[30] Data from BP Statistical Review 2017

Figure 26 illustrates trends in per capita non-hydro renewable consumption by country over the past 26 years. Per capita consumption of non-hydro renewable energy has increased dramatically in most countries, but overall consumption is far higher on a per capita basis in the developed world than in the developing world. The highest growth rates, however, are in the developing world, with non-OECD countries growing at 33.7% per year over the past five years versus OECD countries at 14.5%. China and India increased at 54% per year and 15% per year, respectively, over this timeframe. Of OECD countries, the US and Canada exceeded average growth at 15.4% per year and 16.3% per year, respectively. Global growth over the past five years was 18.8% per year, making non-hydro renewables by far the fastest growing energy source. However, as they are growing from a very small base they remain a small portion of total energy supply.

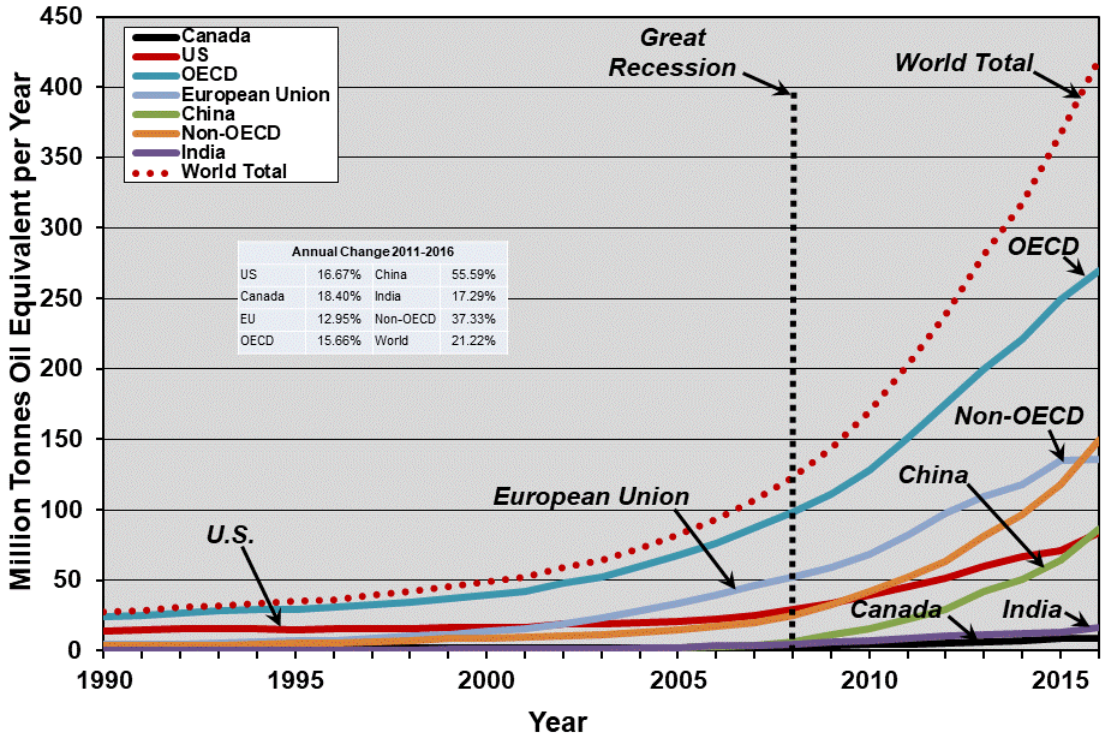
Figure 26: Per capita non-hydro renewable consumption by country from 1990 to 2016.
Although consumption has grown rapidly in all parts of the world, rates of non-hydro renewable consumption are much higher in the developed world than in the developing world.[31]



[31] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 27 illustrates total non-hydro renewable consumption by country over the past 26 years. Given population growth, consumption has been growing globally at 21.2% per year over the past five years. Total consumption in the developed world (represented by OECD countries) has been growing at 15.7% per year. Despite representing just 17% of the world's population, developed countries consumed nearly twice as much non-hydro renewable energy as the developing world. As observed above with per capita consumption, however, growth in consumption of non-hydro renewables is much higher in non-OECD countries, at 37.3% per year over the past five years. Canada, at 18.4% per year, exceeded the non-hydro renewable growth rate in the developed world, but was below the world average. If hydropower is included, however, Canada has a very large component of renewable energy compared to the world average, as noted above.

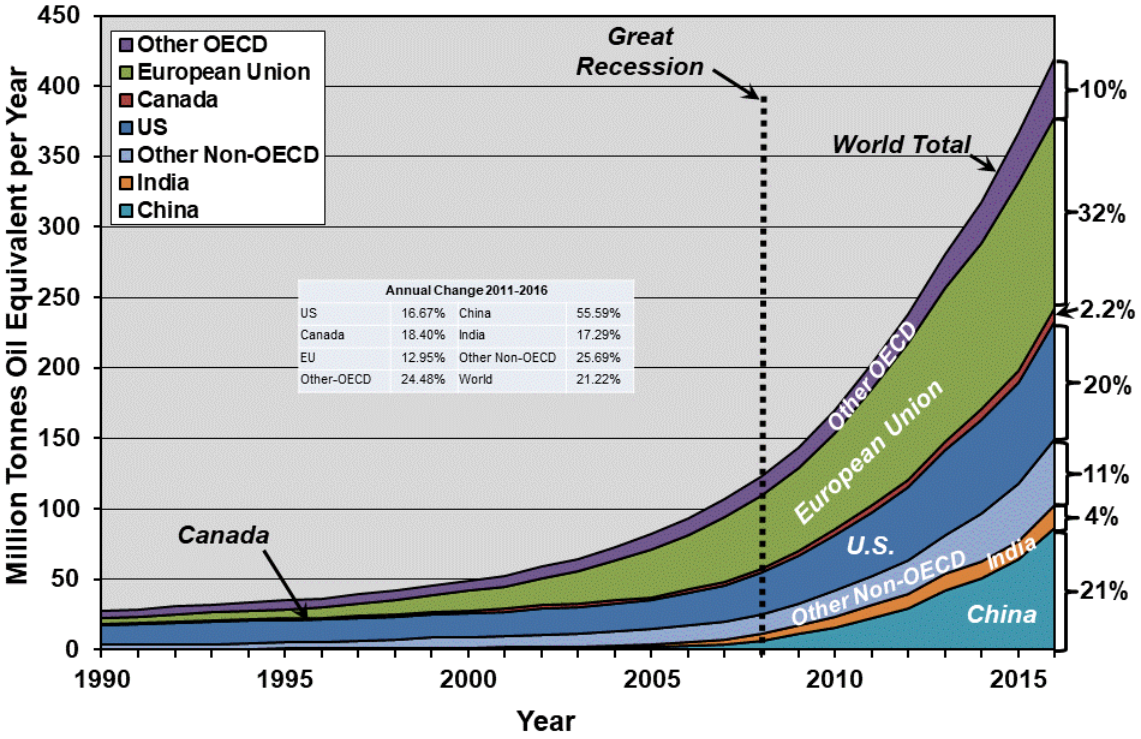
Figure 27: Total non-hydro renewable consumption by country from 1990 to 2016.
Consumption has grown rapidly, particularly in the past decade. The developed world (represented by OECD countries) consumes nearly twice as much non-hydro renewable energy as the developing (non-OECD) countries.[32]



[32] Data from BP Statistical Review 2017

Figure 28 shows a stacked chart of total non-hydro renewable consumption by country over the past 26 years, illustrating the proportions consumed. Total consumption has tripled globally since 2009. The European Union consumed 37% of global non-hydro renewable energy in 2016, and OECD countries collectively consumed two-thirds, making non-hydro renewable energy a rich country's game—so far. However, consumption in non-OECD countries is growing at faster rates than in OECD countries, with most more than doubling since 2009, and China increasing eight-fold since then. Canadian consumption of non-hydro renewable energy has increased by 168% since 2009, and accounted for 2.2% of global non-hydro renewable consumption in 2016.

Figure 28: Total non-hydro renewable consumption by country from 1990 to 2016.
Although the developing world (represented by non-OECD countries) is growing rapidly, it consumes only about a third as much non-hydro renewable energy as OECD countries.[33]



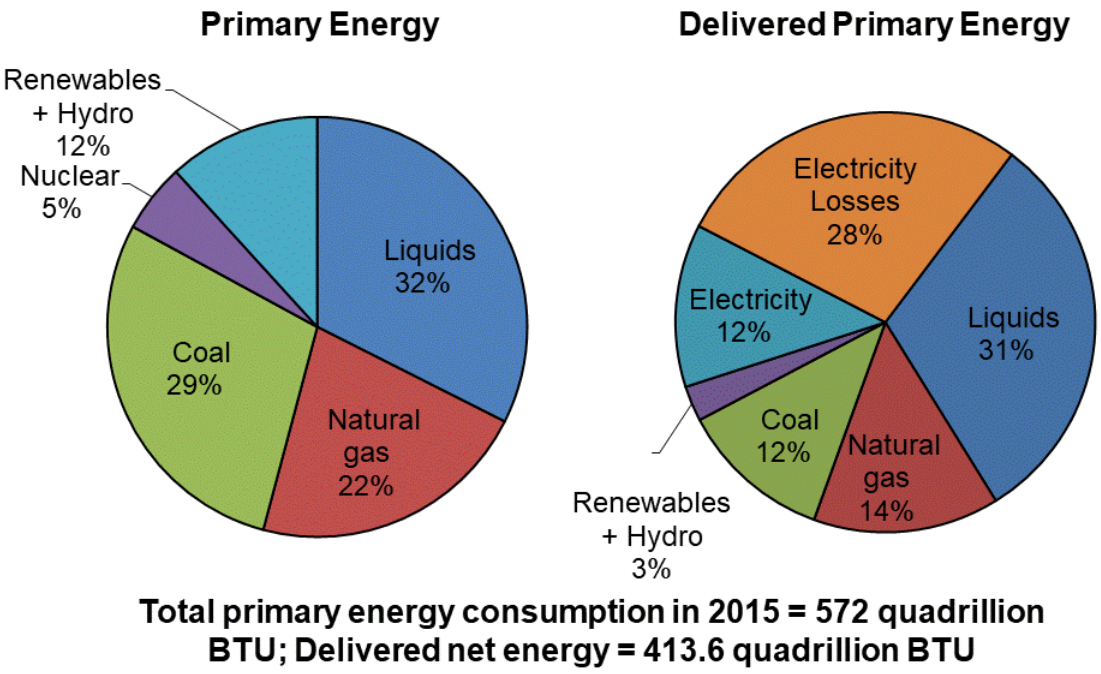
1.2 Delivered energy by fuel and sector

Primary energy undergoes losses as it is converted to a form suitable for end use, which is termed "delivered energy." Principal among these are losses in the conversion of fossil fuels to electricity, but other losses are incurred, for example, in the conversion of crude oil or bitumen to refined petroleum products, and the clean-up and distribution of natural gas from well head to burner tip. Losses in the conversion of coal and natural gas to electricity amount to 55–70% and 45–65%, respectively, of the energy in the input fuel, depending on the technology used. Some losses are also incurred in the transmission of electricity to the point of end use. Electricity is an extremely versatile form of energy, however, and underpins modern life. It is also the principal product of renewable technologies, which will be increasingly important in lowering the carbon footprint of the energy system.

[33] Data from BP Statistical Review 2017

Figure 29 illustrates the conversion of primary energy to delivered energy for the world in 2015. Some 40% of primary energy is used in electricity generation but only 12% of primary energy is consumed as electricity delivered to the point of end use—28% of primary energy is lost in the electric conversion process. The other 60% of primary energy is used in non-electric applications for heat and transport, and as feedstock for petrochemicals and other products.

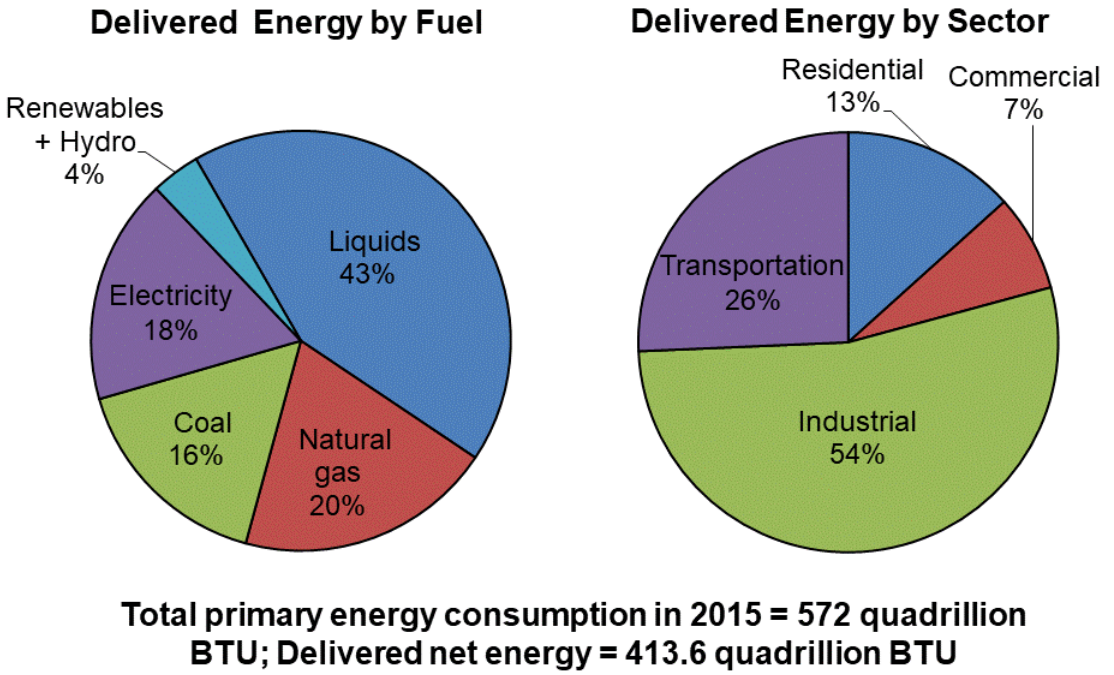
Figure 29: Conversion of primary energy by fuel into end-use delivered energy for the world in 2015.
Energy losses amount to 28%, chiefly due to the generation of electricity by coal and natural gas. Data are from the US Energy Information Administration's 2016 International Energy Outlook.[34]



[34] U.S. Energy Information Administration, 2016, International Energy Outlook, https://www.eia.gov/outlooks/ieo/ . Liquids are mainly oil but include a small component of biofuels and natural gas liquids such as condensate.

Figure 30 illustrates global consumption of delivered energy by fuel and end-use sector in 2015. Electricity amounts to just 18% of delivered energy consumption. Some 78% of delivered energy is fossil fuels used in non-electric applications such as heat, transportation, petrochemical feedstocks and other industrial processes. The industrial sector alone consumes over half of delivered energy and the transportation sector consumes a quarter, with the balance used in the residential and commercial sectors.

Figure 30: Delivered energy consumption by fuel and end-use sector for the world in 2015.
Fossil fuels used for non-electric uses make up 78% of end-use consumption. Data are from the US Energy Information Administration's 2016 International Energy Outlook.[35]

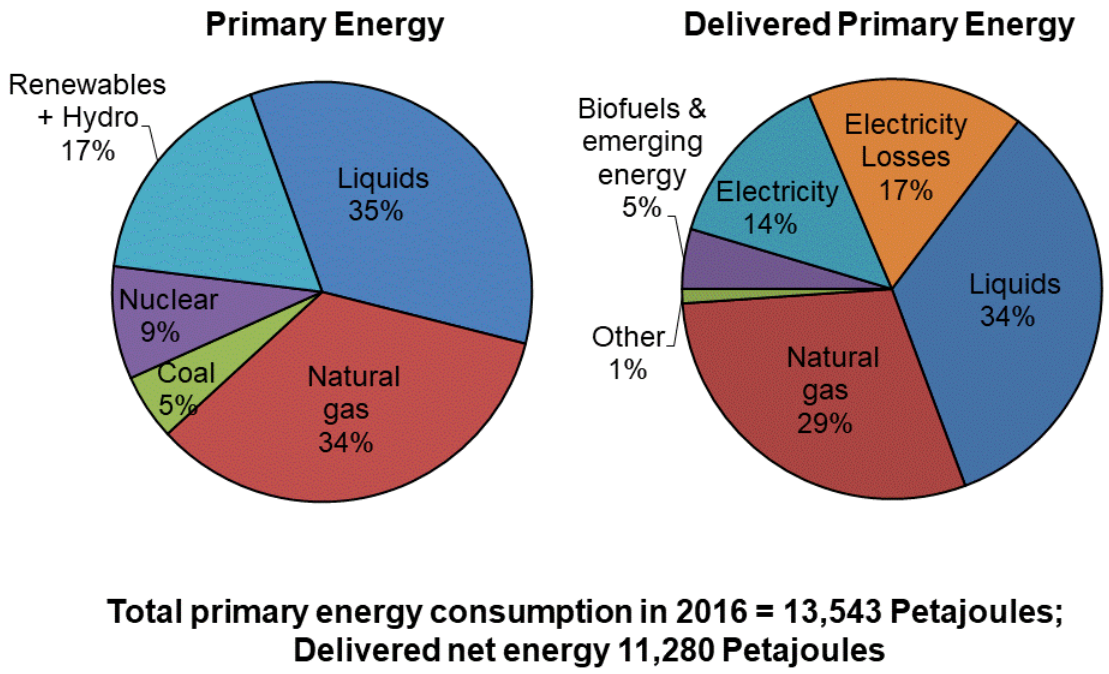


The sheer magnitude of non-electric fossil fuel energy consumption points to the challenge of converting to a world largely run on renewable energy, which would require a much higher level of electrification of all end-use sectors. Electricity is, however, a much more efficient source of energy for some applications, such as transportation, given the superior efficiency of electric motors (80–90% versus 20–40% for internal combustion engines), and a significant proportion of the energy the industrial sector uses is for the production of oil and gas. Hence increased electrification can result in a reduction in end-use energy consumption without impacting consumers. Nonetheless, the scale-up in electrification required to move to a mostly renewable future is daunting, as it would require a several-fold increase in electricity generation (this problem and scenarios for electrification included in Canada's "Mid-Century Long-Term Low-Greenhouse Gas Development Strategy" are discussed in a later section).

[35] U.S. Energy Information Administration, 2016, International Energy Outlook, https://www.eia.gov/outlooks/ieo/

Figure 31 illustrates the conversion of primary energy to delivered energy for Canada in 2016. Canada generates a large proportion of its electricity from hydropower, hence energy losses from conversion to electricity are considerably lower than for the world as a whole: 17% versus 28% of primary energy consumption. Furthermore, electricity comprises a higher percentage of delivered primary energy in Canada compared to the world: 14% versus 12%. Some 69% of delivered primary energy in Canada was used in non-electric applications for heat and transport, and as feedstock for petrochemicals and other products in 2016.

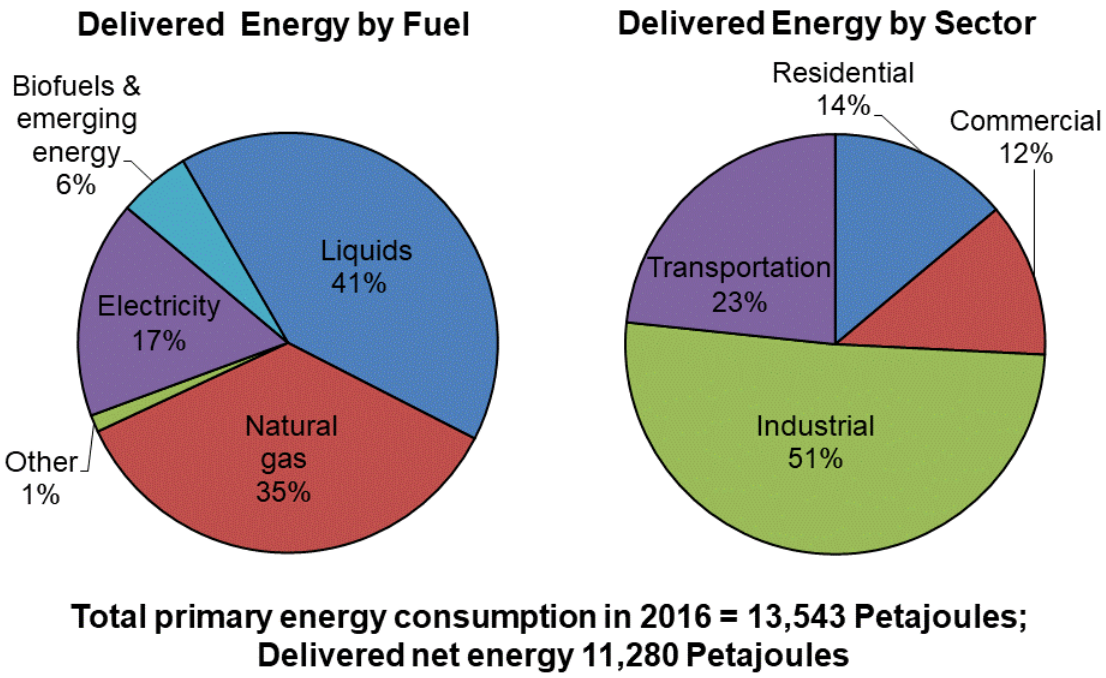
Figure 31: Conversion of primary energy by fuel into end-use delivered energy for Canada in 2016.
Energy losses amount to 17%, chiefly due to generation of electricity by coal and natural gas. Data are from the National Energy Board's Energy Futures *report.*[36] *"Renewables" include landfill gas.*



[36] National Energy Board, October 2017, https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2017/2017nrgftr-eng.pdf , Appendices, https://apps.neb-one.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA

Figure 32 illustrates Canadian consumption of delivered energy by fuel and end-use sector in 2016. Electricity comprised just 17% of Canadian delivered energy consumption in 2016 (comparable with the world as a whole at 18%). Some 76% of delivered energy was fossil fuels used in non-electric applications such as heat, transportation and petrochemical feedstocks. The industrial sector alone consumed half of delivered energy and the transportation sector consumed a quarter, with the balance used in the residential and commercial sectors.

Figure 32: Delivered energy consumption in Canada by fuel and end-use sector in 2016.
Fossil fuels used for non-electric uses make up 76% of end-use consumption. Data are from the National Energy Board's Energy Futures *report.*[37] *"Renewables" include landfill gas.*



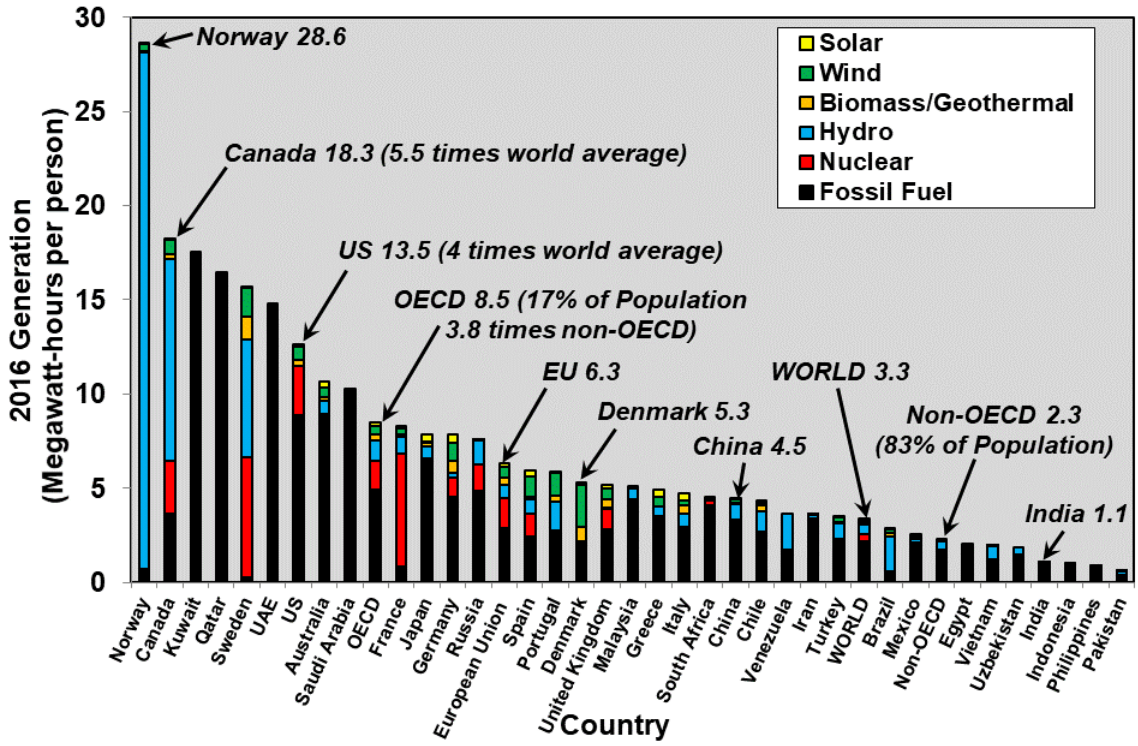
[37] National Energy Board, October 2017, https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2017/2017nrgftr-eng.pdf , Appendices, https://apps.neb-one.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA

1.3 Electricity generation and consumption

Electricity deserves a closer examination, given that renewable energy sources such as wind and solar produce electricity directly. For there to be a much higher penetration rate of renewables into the world's overall energy system, a much greater proportion of end-use consumption will need to be converted to electricity.

Figure 33 illustrates per capita generation of electricity by country and fuel in 2016. As with energy in general, the industrialized world consumes a great deal more electricity than the developing world. OECD countries, which constitute 17% of the world's population, generate nearly four times as much electricity per capita as non-OECD countries. India generates one third of the per capita electricity of the world average, and less than one quarter that of China. Norway is one of the highest per capita generators of electricity in the world with its extensive hydropower resources, much of which is exported to other European countries. Americans generate four times the world average, mostly from fossil fuels and nuclear power, and Canadians generate more than five times the world average, much of it from hydropower, of which a significant proportion is exported, particularly from Quebec.

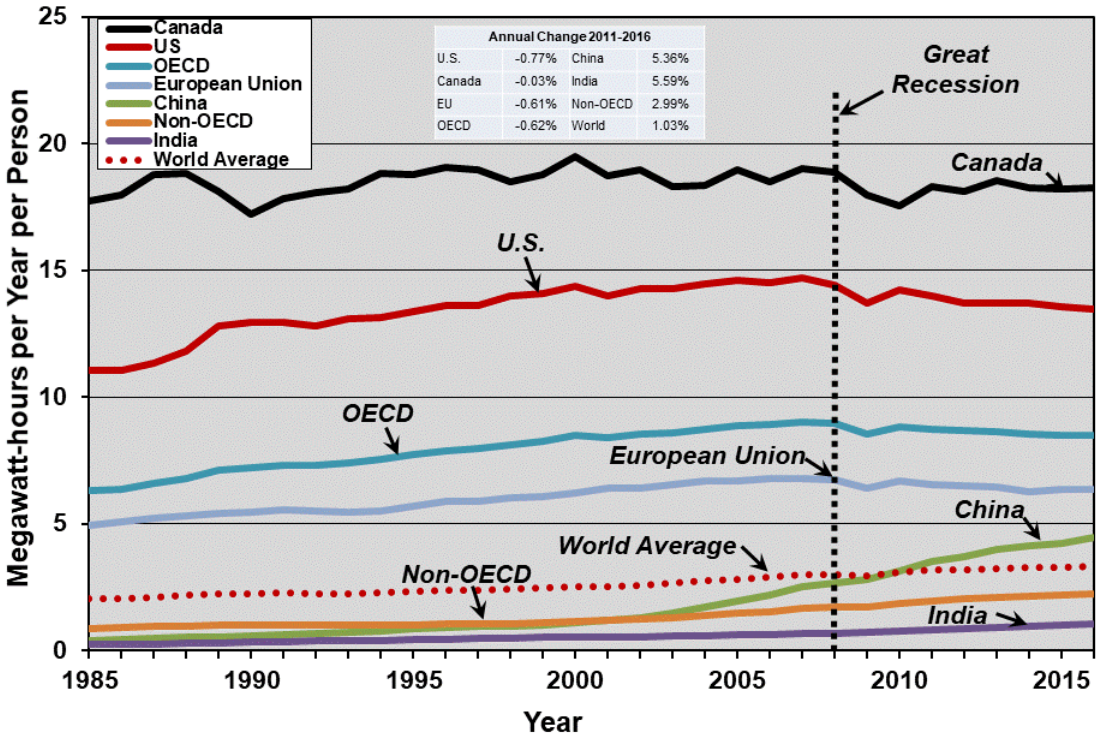
Figure 33: Per capita generation of electricity by country and fuel in 2016.[38]



[38] Data from BP Statistical Review 2017 and World Bank population data

Figure 34 illustrates trends in per capita generation of electricity by country over the past 31 years. Globally, per capita generation has been rising at 1% per year over the past five years. Per capita generation in OECD countries, however, although at much higher levels than in developing countries, has fallen 6% from its peak in 2007. Per capita generation also peaked in the US in 2007 and is down 8.5%. In Canada, per capita generation peaked in 2000 and is down 6.2% as of 2016. In contrast, the developing world has grown rapidly, with China up 5.4% per year over the past five years, India up 5.6% per year and non-OECD countries as a whole up 3% per year. Per capita generation is likely to continue to grow very strongly in the developing world. The decline in the industrialized world contradicts the trend that would seem necessary to replace many of the current non-electric end uses of energy with renewables.

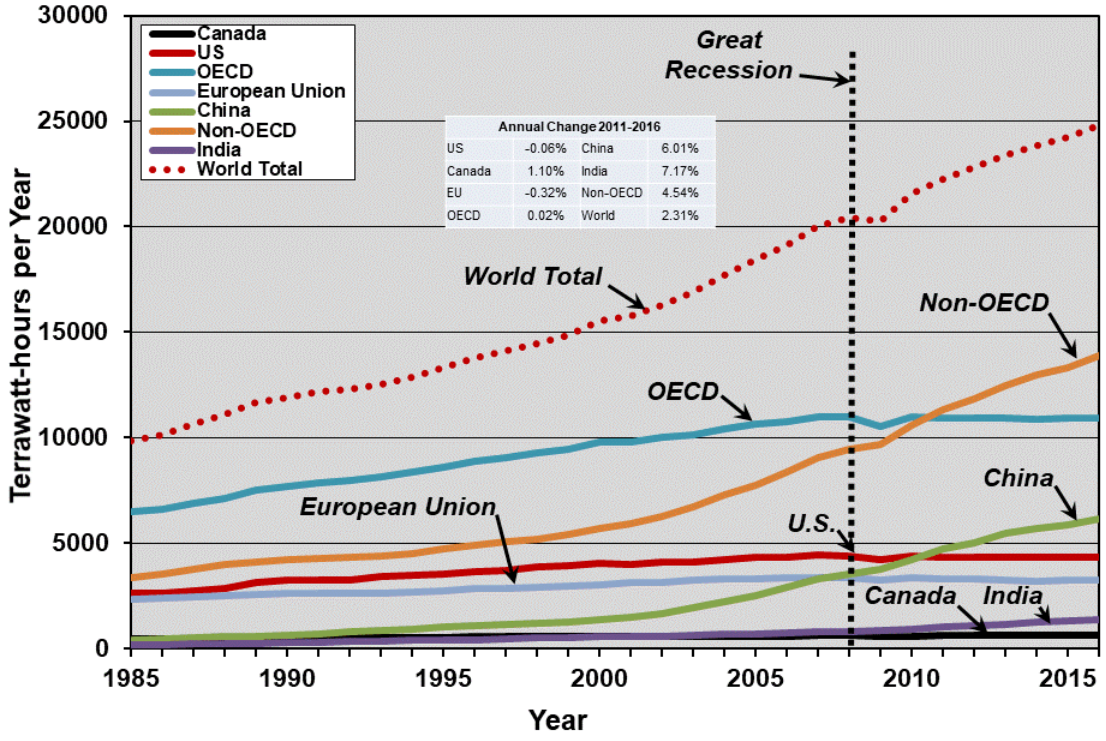
Figure 34: Per capita generation of electricity by country from 1985 to 2016. [39]



[39] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 35 illustrates total electricity generation by country over the past 31 years. World generation has grown at 2.3% per year over the past five years, with the developed world essentially flat and the developing world (represented by non-OECD countries) growing at 4.5% per year. Electricity generation in China has more than quadrupled since 2000, and in India it has more than doubled. US generation is down 2% since peaking in 2007, and Canadian generation has been growing at 1.1% per year over the past five years.

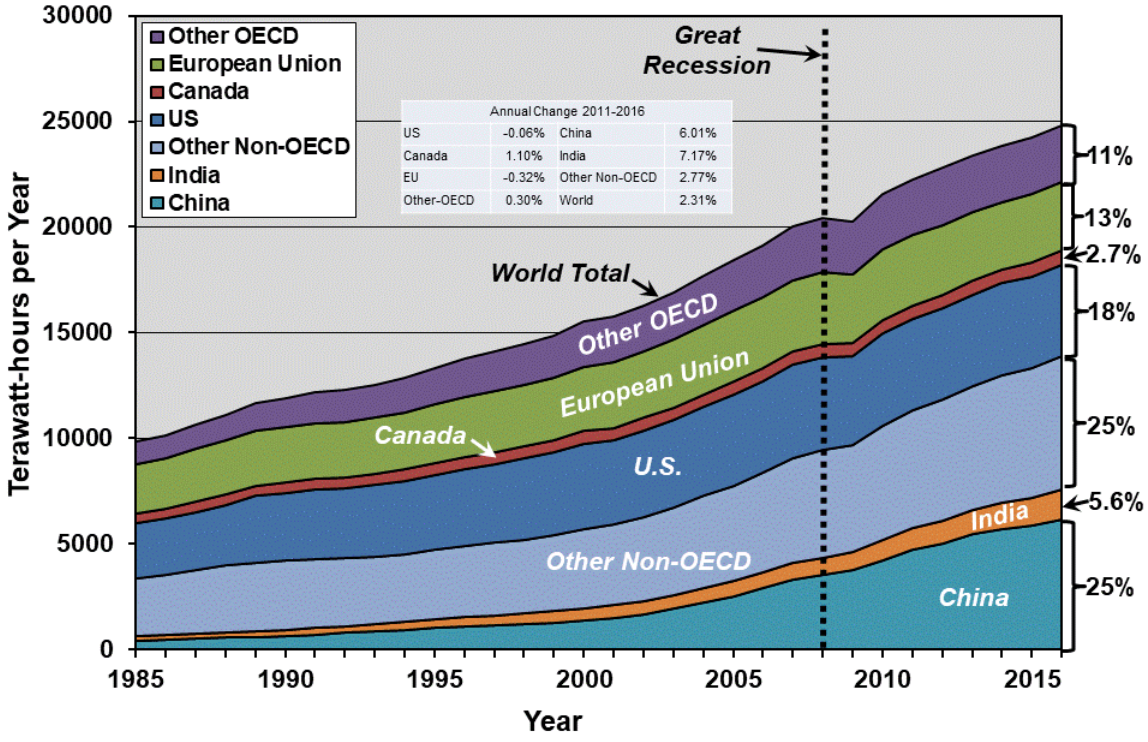
Figure 35: Total electricity generation by country from 1985 to 2016. [40]



[40] Data from BP Statistical Review 2017

Figure 36 shows a stacked chart of total electricity generation by country over the past 31 years, illustrating the proportions consumed. Total generation has doubled globally since 1992. China is now the largest consumer of electricity in the world at 25%, followed by the US at 18% and the European Union at 13%. Canadian consumption has been relatively stable for the past 10 years, and accounted for 2.7% of global electricity generation in 2016.

Figure 36: Total electricity generation by country from 1985 to 2016.
World generation has doubled since 1990 and China became the largest consumer of electricity in the world in 2011.[41]

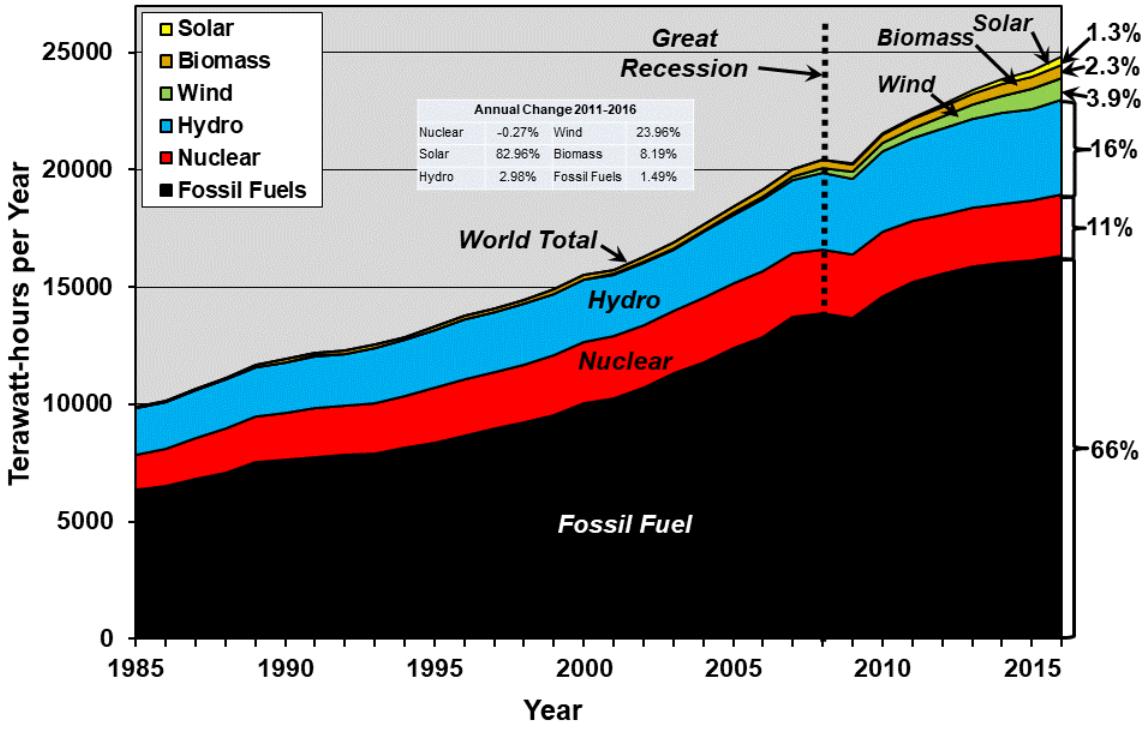


[41] Data from BP Statistical Review 2017

1.3.1 Electricity generation by fuel

Figure 37 illustrates electricity generation by fuel. Fossil fuels, primarily coal and natural gas, provided two-thirds of global electricity generation in 2016, followed by large hydro and nuclear, at 16% and 11%, respectively. Non-hydro renewables—wind, solar and biomass—provided just 7.5%, although they are growing rapidly, with solar averaging 83% per year growth over the past five years and wind 24% per year. Fossil fuel and hydro generation has grown also, but at much slower rates, averaging 1.5% per year and 3% per year over this period. Nuclear has been slowly declining.

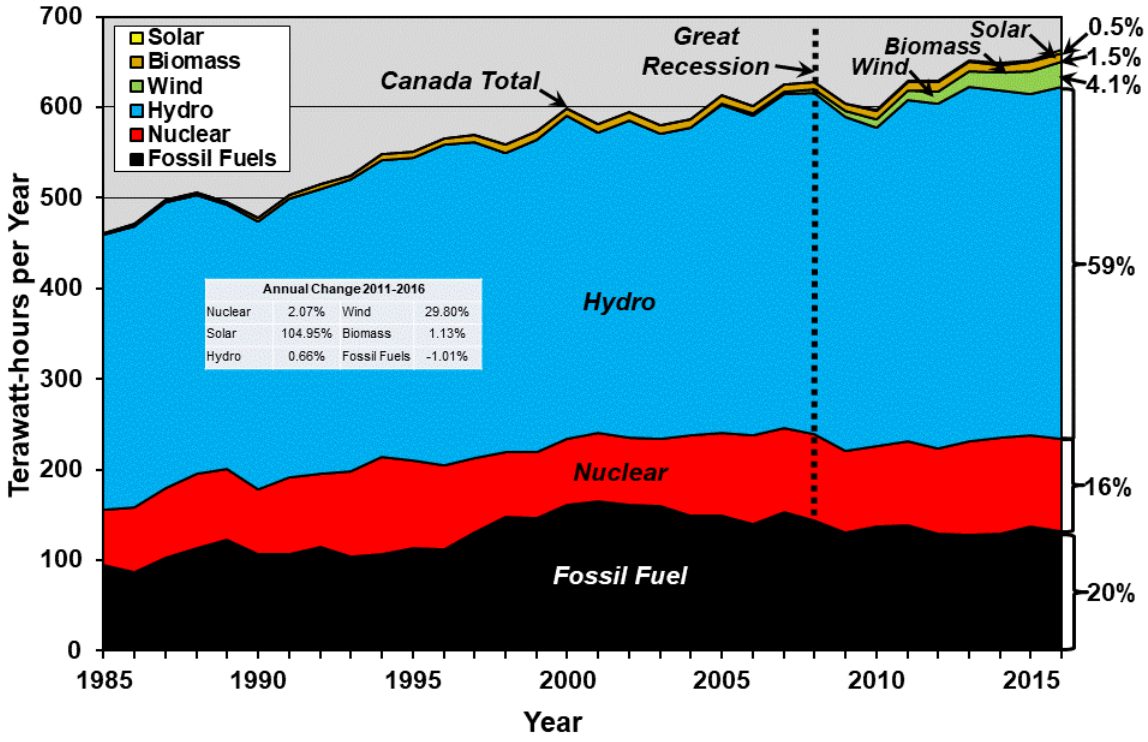
Figure 37: World electricity generation by fuel from 1985 to 2016.
Fossil fuels remain dominant—although non-hydro renewables are growing rapidly, but from a small base.[42]



[42] Data from BP Statistical Review 2017

Canada's electricity system is dominated by large hydro, making it one of the cleanest in the world from a carbon emissions point of view (see Figure 38). Fossil fuel use for electricity generation in Canada has been declining at an average rate of 1% per year over the past five years. Nuclear power generation has increased somewhat in recent years with the refurbishment of some reactors, although the all-time peak was in 1994. Some 65% of Canadian nuclear generation capacity comes from reactors that are more than 30 years old, and 14% from reactors more than 40 years old, meaning more refurbishments and/or replacements will be needed in coming years to maintain nuclear generation capacity.[43] Although non-hydro renewables such as wind and solar have been growing very rapidly in recent years, they made up just 6.1% of generation in 2016.

Figure 38: Canadian electricity generation by fuel from 1985 to 2016.
Large hydro is dominant although non-hydro renewables have grown significantly in recent years. Fossil fuel generation peaked in 2001 and had declined 20% by 2016.[44]



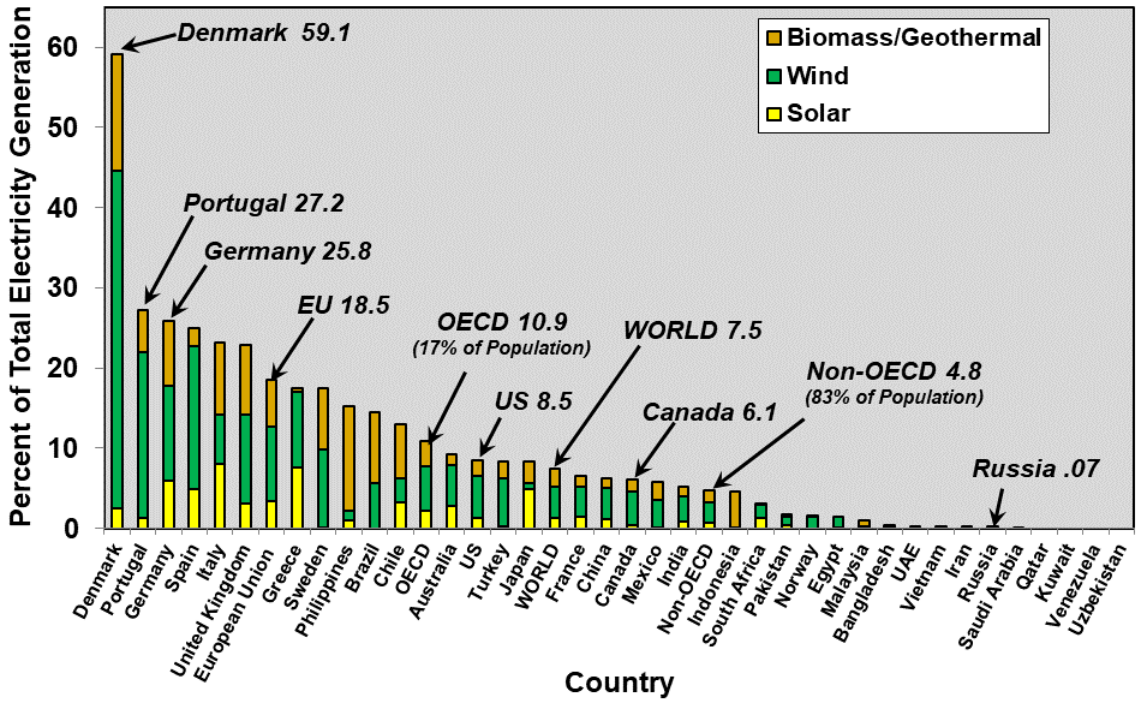
[43] International Atomic Energy Association, Power Reactor Information System, accessed October 10, 2016, https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=CA

[44] Data from BP Statistical Review 2017

1.3.2 Electricity generation by renewables

In terms of electricity generation from non-hydro renewables, Canada, at 6.1%, remained below the world average of 7.5% in 2016, and far below countries like Denmark, at 59.1% (see Figure 39). Non-hydro renewables have potential for considerable upward scaling, but as they are being scaled from a small base significant penetration will take some time. Non-hydro renewables also have issues such as intermittency, seasonal fluctuations and the need for more transmission infrastructure, which must be planned for as they are scaled upward.

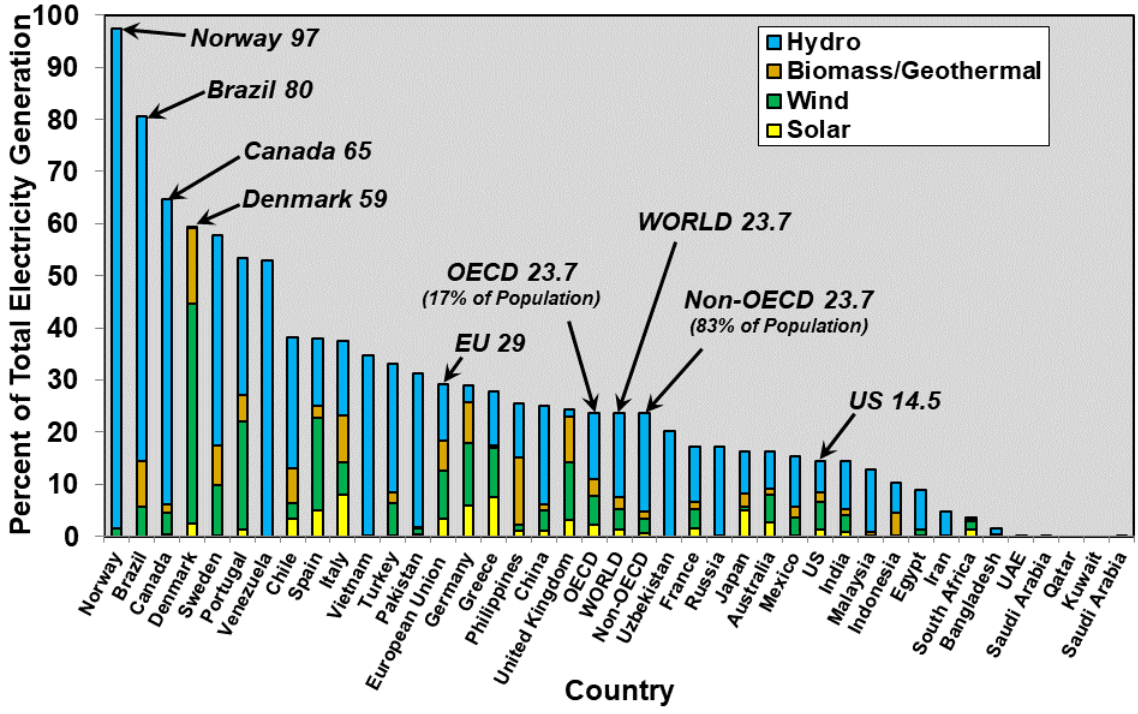
Figure 39: Non-hydro renewable electricity generation by country in 2016.
Canada is below the world average and far below countries such as Denmark, Portugal, Spain and Germany.[45]



[45] Data from BP Statistical Review 2017

If large hydro is included, Canada has one of the cleanest electricity systems in the world, with 65% of electricity generated by renewable sources—nearly triple the world average (see Figure 40). Large hydro has significant environmental impacts, however, and many of the prime sites close to demand loads have already been developed. Large hydro generates more than twice as much electricity globally as non-hydro renewables combined, and in Canada generates 10 times as much.

Figure 40: Electricity generation from all renewable sources by country in 2016.
Canada is near the top in this comparison. Large hydro generates more than twice as much electricity globally as non-hydro renewables combined. [46]



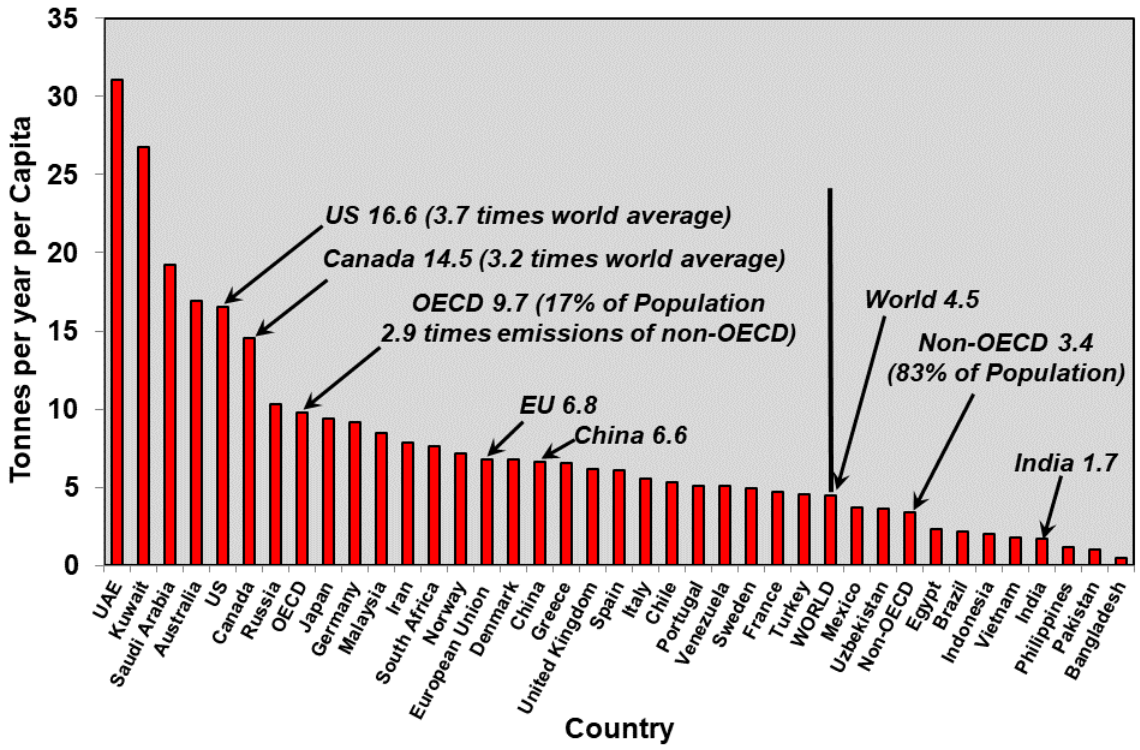
[46] Data from BP Statistical Review 2017

1.4 Greenhouse gas emissions

Carbon dioxide emissions from the combustion of fossil fuels are the major greenhouse gas concern for global warming, given carbon dioxide's longevity in the atmosphere. Although there are several even more potent greenhouse gases, such as methane, they typically have much shorter residence times in the atmosphere (and non-fossil fuel activities such as livestock and land disturbance also release considerable amounts of greenhouse gas). Carbon dioxide emissions from fossil fuels have tripled globally since 1965, although there has been very little growth since 2013.

Figure 41 illustrates per capita emissions of carbon dioxide by country in 2016. Canadians emit more than triple the world average, despite the fact that Canada's electricity sector has a high proportion of carbon-free generation. This is primarily a result of emissions in the transportation, building and industrial sectors. The US, at 3.7 times the world average, is higher than Canada mainly due to the carbon intensity of its electrical sector. The European Union has on average less than half of the per capita emissions of Canada. Industrialized countries represented by the OECD have nearly triple the per capita carbon dioxide footprint of developing countries. Looking at the two largest developing countries, China has nearly quadruple the per capita emissions footprint of India (China is now close to the per capita emissions of the European Union).

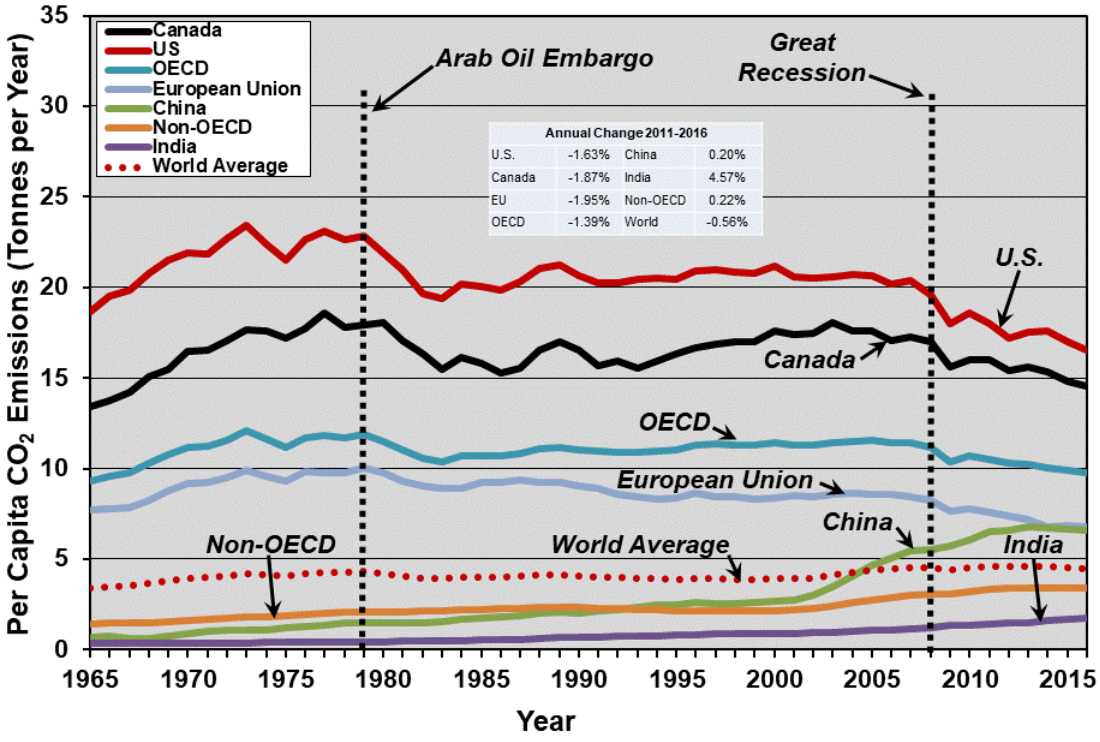
Figure 41: Per capita carbon dioxide emissions by country in 2016.[47]



[47] Data from BP Statistical Review 2017 and World Bank population statistics for 2016

Figure 42 illustrates trends in per capita carbon dioxide emissions by country over the past 50 years. Per capita emissions in the industrialized world, although much higher than in the developing world, have been declining over the past decade. Canada's per capita emissions have declined at an average annual rate of 1.87% over the past five years, and the US has been declining at 1.63% per year. By contrast, China's emissions have increased at .2% per year and India's have increased at 4.57% per year over the same period. The world as a whole has declined at .56% per year on a per capita basis over the past five years.

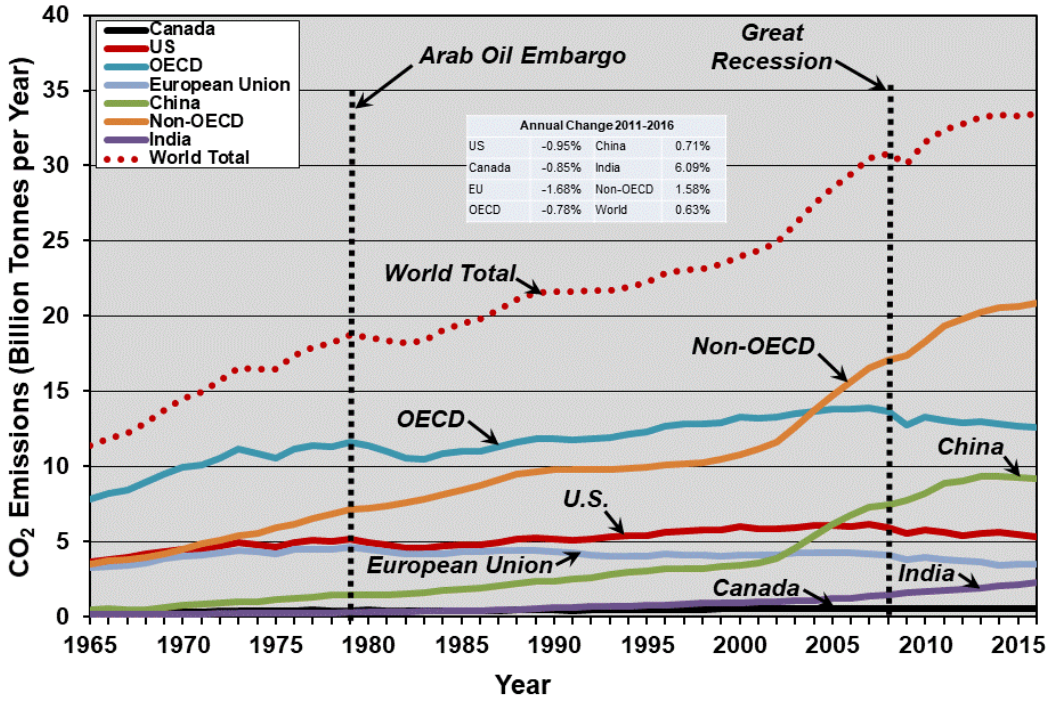
Figure 42: Per capita carbon dioxide emissions by country from 1965 to 2016.[48]



[48] Data from BP Statistical Review 2017 and World Bank population statistics

Figure 43 illustrates total carbon dioxide emissions by country over the past 50 years. Coupled with population growth, world emissions have grown at .63% per year over the past five years but have been essentially flat since 2013. Total emissions in Canada have declined at an annual rate of 0.85% over this period and the US has declined by .95% per year. Overall emissions have declined in industrialized (OECD) countries at .78% per year and have grown at 1.58% per year in the developing world. Non-OECD emissions have exceeded OECD emissions since 2004. Annual emissions in China and India have grown at .71% per year and 6.09% per year, respectively, over the past five years (although China's emissions have declined slightly since 2014).

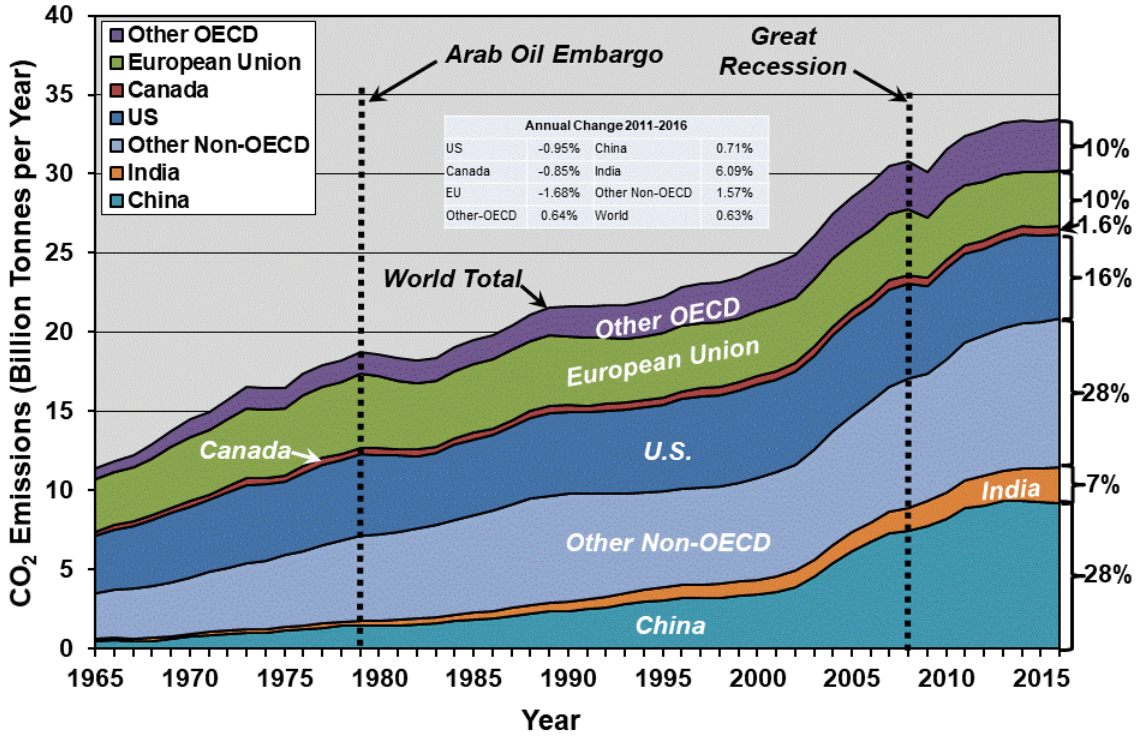
Figure 43: Total carbon dioxide emissions by country from 1965 to 2016.[49]



[49] Data from BP Statistical Review 2017

Figure 44 shows a stacked chart of total carbon dioxide emissions by country over the past 50 years, illustrating the proportions of the global total emitted by each country. Emissions have tripled globally since 1965 and have increased by 39% since 2000. The developing world now accounts for 63% of global emissions and China, the world's largest emitter, accounts for 28%. Canada accounts for just 1.6% of global emissions given its relatively small population, even though its emissions on a per capita basis are very high.

Figure 44: Total carbon dioxide emissions by country from 1965 to 2016.
World emissions have tripled since 1965 and China is now the largest emitter in the world.[50]

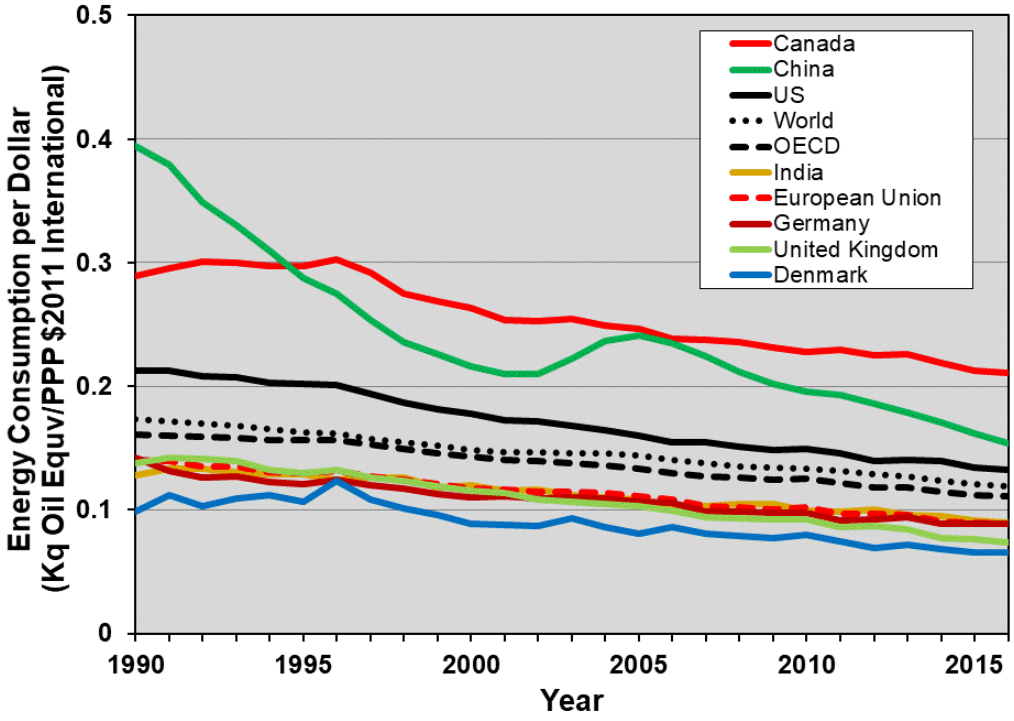


[50] Data from BP Statistical Review 2017

1.5 Energy and the economy

Economic activity and energy consumption have historically been closely linked, although energy intensity—the amount of energy used per dollar of gross domestic product (GDP)—has decreased over time. Figure 45 illustrates the energy intensity trends for developed and developing countries over the past 25 years. Although Canadian energy intensity has improved, it is still one of the highest in the world, higher even than China, which relies extensively on coal for electricity generation. The energy intensity of European countries, and especially Denmark with its high proportion of renewable energy, is less than half that of Canada, reflecting greater efficiency in the coupling of energy to the economy.[51]

Figure 45: Energy intensity by country from 1990 to 2016.
GDP is expressed as purchasing power parity (PPP) in constant 2011 international dollars (an international dollar has the same purchasing power over GDP as the US dollar has in the United States).[52]

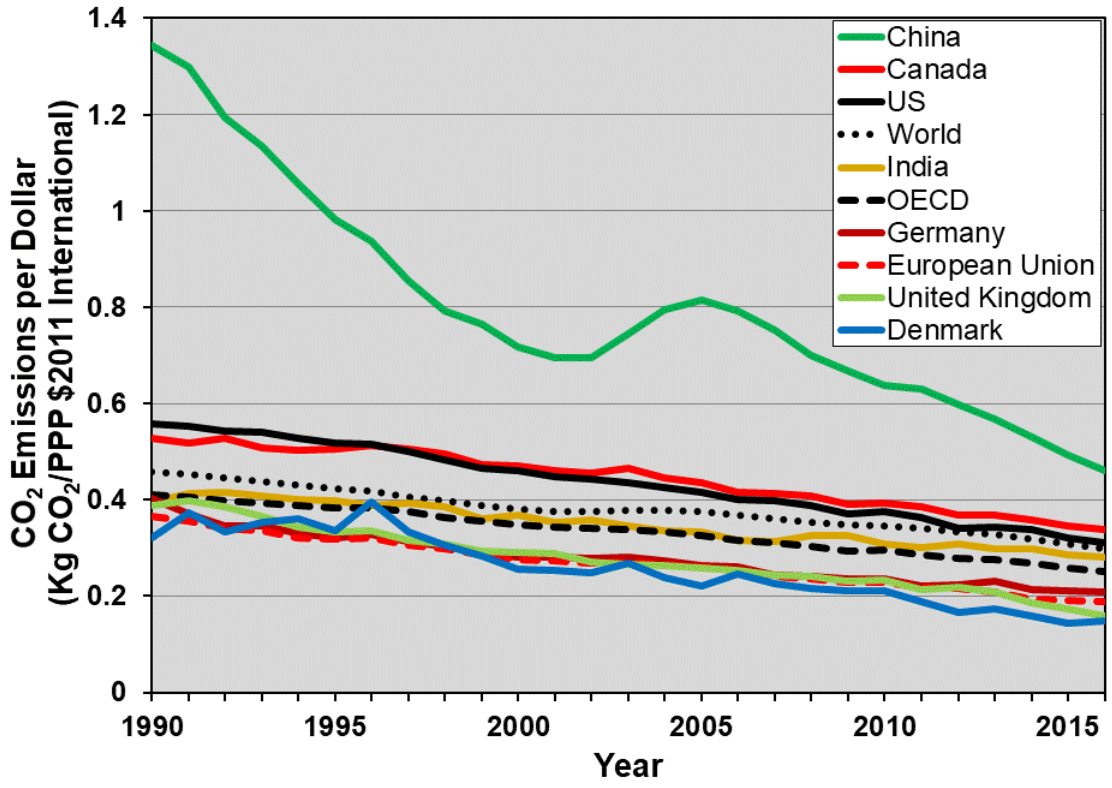


[51] World Bank, Data Bank of World Development Indicators, retrieved August18, 2017, http://databank.worldbank.org/data/reports.aspx?source=2&country=CAN ; Energy consumption from BP Statistical Review of World Energy 2017.

[52] GDP data from World Bank, 2017; Energy consumption data from BP Statistical Review, 2017

Greenhouse gas emissions intensity—the amount of greenhouse gas emitted per dollar of GDP— has also decreased over time with the improvement in energy intensity and efficiency. Figure 46 illustrates carbon dioxide emissions from fossil fuels per dollar of GDP. In this case Canada fares much better than China, given that a large proportion of Canada's electricity is generated by carbon-free sources, but it still ranks above the world average and is much higher than European nations. Denmark, with among the world's highest per capita consumption of renewable energy, has less than half the emissions intensity of Canada.[53]

Figure 46: Carbon dioxide emissions intensity from fossil fuel combustion by country from 1990 to 2016.
GDP is expressed as purchasing power parity (PPP) in constant 2011 international dollars (an international dollar has the same purchasing power over GDP as the US dollar has in the United States).[54]



The decrease in both energy- and emissions-intensity is sometimes cited as reason to believe that energy and emissions are becoming "de-coupled" from the economy, and the world can enjoy continued economic growth while at the same time reducing energy consumption and emissions. Although improvements in efficiency will allow further decreases in energy intensity, it is unlikely to ever become completely decoupled from the economy. Emissions intensity will benefit from both efficiency gains and the increased use of renewable energy. However, as renewable energy is being scaled from a very small base, hydrocarbons will likely remain a significant source of energy for decades to come.

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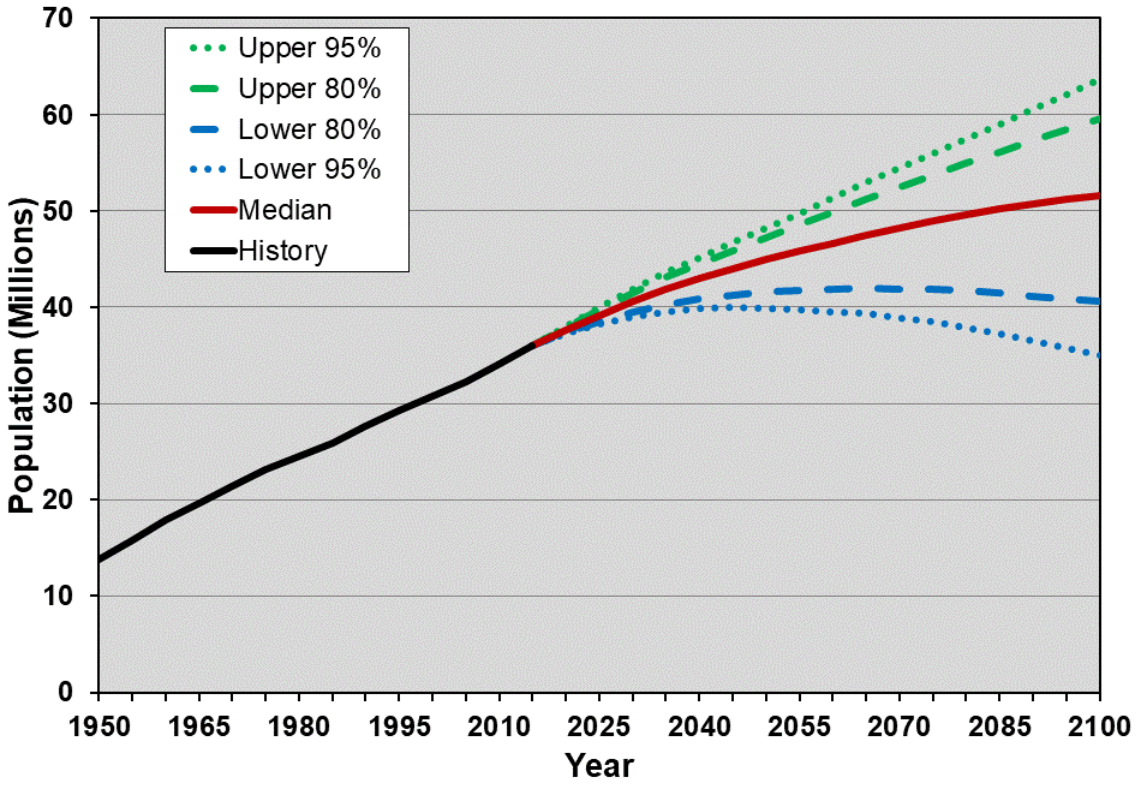
[53] World Bank, Data Bank of World Development Indicators, retrieved October 20, 2016, http://databank.worldbank.org/data/reports.aspx?source=2&country=CAN ; Carbon dioxide emissions from BP Statistical Review of World Energy 2016.

[54] GDP data from World Bank, 2017; CO_2 emissions data from BP Statistical Review, 2017

Another factor that energy- and emissions-intensity statistics mask is the total impact of energy consumption and emissions given that GDP per person is growing along with population. According to the United Nations, the world has a median expectancy of reaching 11.1 billion people by 2100, from 7.5 billion at present, and Canada can expect to grow from 36.6 million at present to more than 51 million in 2100 (see Figure 47).[55]

Figure 47: United Nations history and projections of population in Canada through to the year 2100.
The median estimate would see Canadian population reach more than 51 million by 2100 from 36 million at present. [56]



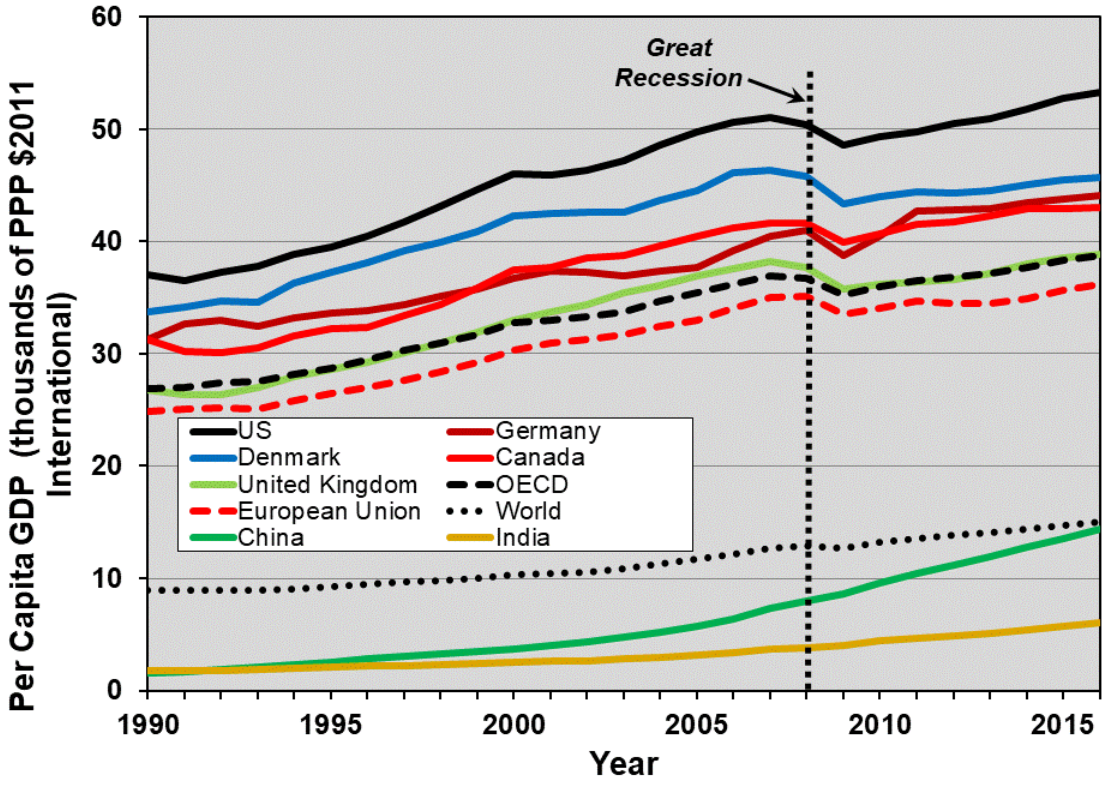
[55] United Nations, 2017, Probabilistic Population Projections based on the World Population Prospects: The 2017 Revision. Population Division, DESA. http://esa.un.org/unpd/ppp/

[56] Data from U.N. World Population Prospects: The 2017 Revision

GDP per capita and population growth serve to keep energy consumption and emissions rising, despite declining energy- and emissions-intensity. Figure 48 illustrates the growth in per capita GDP over the past 25 years. There is a great inequity between developed and developing countries. Per capita GDP in the US, for example, is three and a half times the world average, and nearly four times that of China and nine times that of India. The developing world, however, aspires to developed-world levels of consumption, and GDP per capita in countries like China is growing at much higher rates than in the developed world.[57]

Figure 48: GDP per capita by country from 1990 to 2016.

GDP is expressed as purchasing power parity (PPP) in constant 2011 international dollars (an international dollar has the same purchasing power over GDP as the US dollar has in the United States).[58]



[57] World Bank, Data Bank of World Development Indicators, retrieved August 18, 2017 http://databank.worldbank.org/data/reports.aspx?source=2&country=CAN

[58] Per capita GDP data from World Bank, 2017

Table 1 illustrates the impact of growth in GDP per capita and population on energy consumption and emissions over the past five years. World energy consumption is up by 1.32% per year and emissions are up by .63% per year. Developed countries are growing at low rates or declining in terms of energy consumption and emissions. Canada, for example, is growing at just 0.13% per year in energy consumption and declining at 0.85% per year in emissions. The developing world, however, is growing aggressively, with China and India up 2.7% and 5.5% per year in energy consumption and .71% per year and 6.1% per year in emissions, respectively. Given the fact that the developing world constitutes more than 80% of the world's population, aspirations for much higher economic prosperity coupled with population growth represent major challenges in curtailing global emissions and meeting future energy requirements.

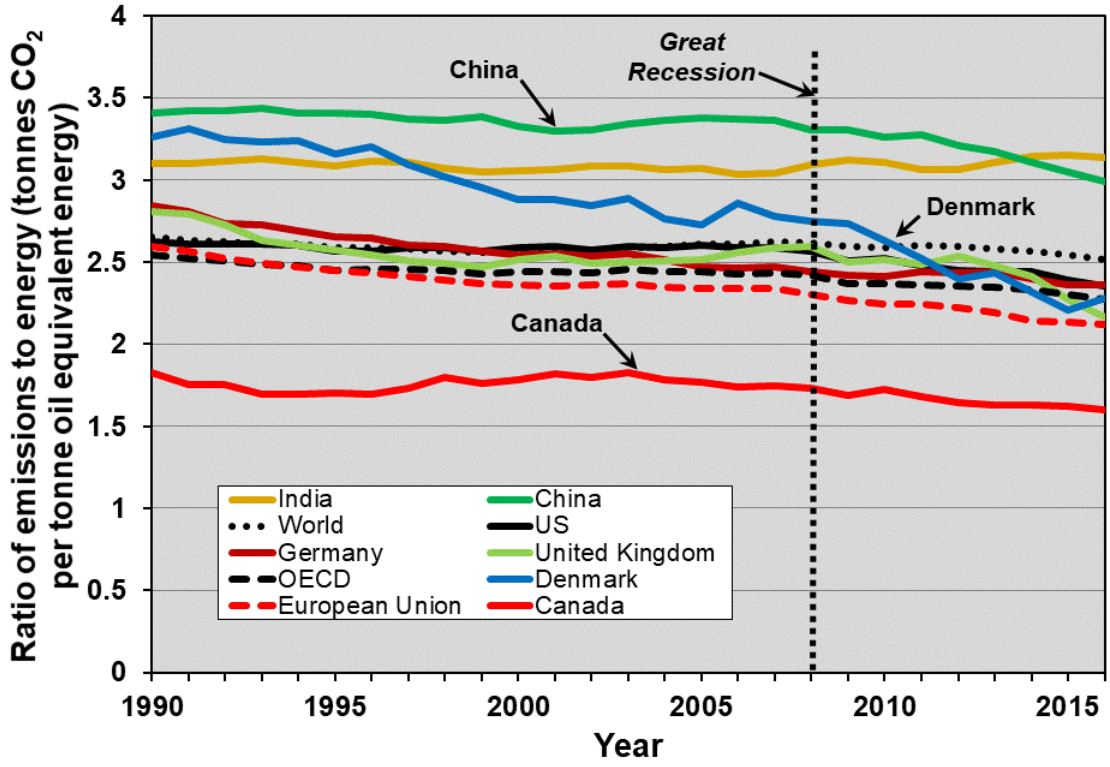
Table 1: Average annual percentage change in energy consumption, emissions and GDP by country from 2011 to 2016.

Although energy intensity is down 1.89% per year for the world over this period, energy consumption is rising at 1.32% per year. Similarly, emissions intensity for the world is down 2.48% per year, but total emissions are rising at .63% per year.

	Energy intensity	Energy per capita	Total energy	Emissions intensity	Emissions per capita	Total emissions	GDP per capita
US	-1.91%	-0.64%	0.07%	-2.83%	-1.63%	-0.95%	1.40%
Canada	-1.62%	-0.95%	0.13%	-2.51%	-1.87%	-0.85%	0.73%
Denmark	-2.50%	-1.99%	-1.47%	-4.16%	-3.70%	-3.23%	0.58%
Germany	-0.56%	0.07%	0.66%	-1.19%	-0.59%	-0.01%	0.65%
United Kingdom	-2.91%	-1.76%	-1.07%	-5.15%	-4.15%	-3.56%	1.34%
China	-4.04%	2.13%	2.70%	-5.43%	0.20%	0.71%	7.74%
India	-1.75%	3.98%	5.46%	-1.30%	4.57%	6.09%	6.28%
World	-1.89%	0.09%	1.32%	-2.48%	-0.56%	0.63%	2.19%
OECD	-1.74%	-0.66%	-0.03%	-2.43%	-1.39%	-0.78%	1.18%
European Union	-1.71%	-0.92%	-0.64%	-2.69%	-1.95%	-1.68%	0.86%

Given the importance of energy to GDP, and energy's linkage to emissions, another measure of the degree to which energy is being decarbonized is the emissions per unit of energy production. Figure 49 illustrates fossil fuel carbon dioxide emissions per unit of energy consumption. Progress towards decarbonization has been very slow, with the exception of countries like Denmark, which has rapidly ramped up renewable energy. Nonetheless, Canada, with its large component of renewable hydropower and nuclear, has a lower carbon dioxide per unit of energy consumption footprint than the world average—and even lower than Denmark's. Although Canada's footprint by this measure is declining, it is doing so very slowly.

Figure 49: Carbon dioxide emissions from fossil fuel combustion per unit of energy produced from 1990 to 2016 (tonnes carbon dioxide per tonne of oil-equivalent energy).
In tonnes of CO_2 per tonne of oil-equivalent energy. CO_2 emissions noted here are from fossil fuels only.[59]



Further reading

To find other sections of this report, download the full report or access related resources, please visit energyoutlook.ca.

[59] Data from BP Statistical Review 2017

This paper is part of the Corporate Mapping Project (CMP), a research and public engagement initiative investigating the power of the fossil fuel industry. The CMP is jointly led by the University of Victoria, the Canadian Centre for Policy Alternatives and the Parkland Institute. This research was supported by the Social Science and Humanities Research Council of Canada (SSHRC).

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