Canada's Energy Future: The Path to Transition

Parkland Events:
University of Calgary
University of Alberta

March 4th and 5th, 2019

J. David Hughes
Global Sustainability Research Inc.

The Ideal Transition:

- ***Business-as-usual economic growth***

- ***Energy based on 100% renewable sources, not finite fossil fuels***

- ***Displaced workers re-employed in a new economic paradigm***

- ***Climate problem solved***

To understand how difficult this might be <u>these key points will be covered:</u>

- ***Energy sources and consumption trends***

- ***The link between energy, emissions and economic growth***

- ***The scale of the climate problem***

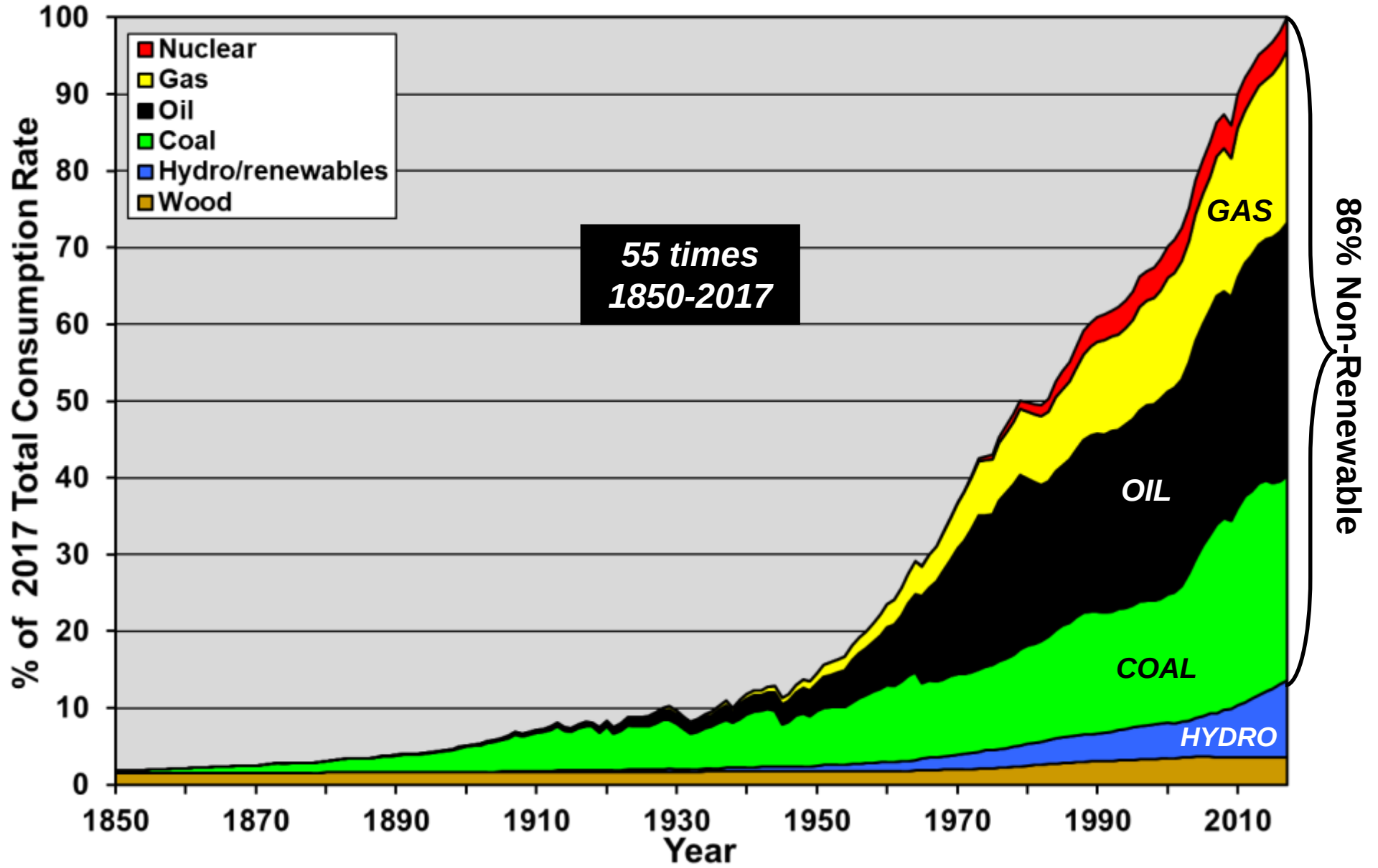
- ***Forecasts of energy production and consumption***

- ***Canada's energy sources and consumption trends***

- ***Emissions trends - Canada's and the world's progress so far***

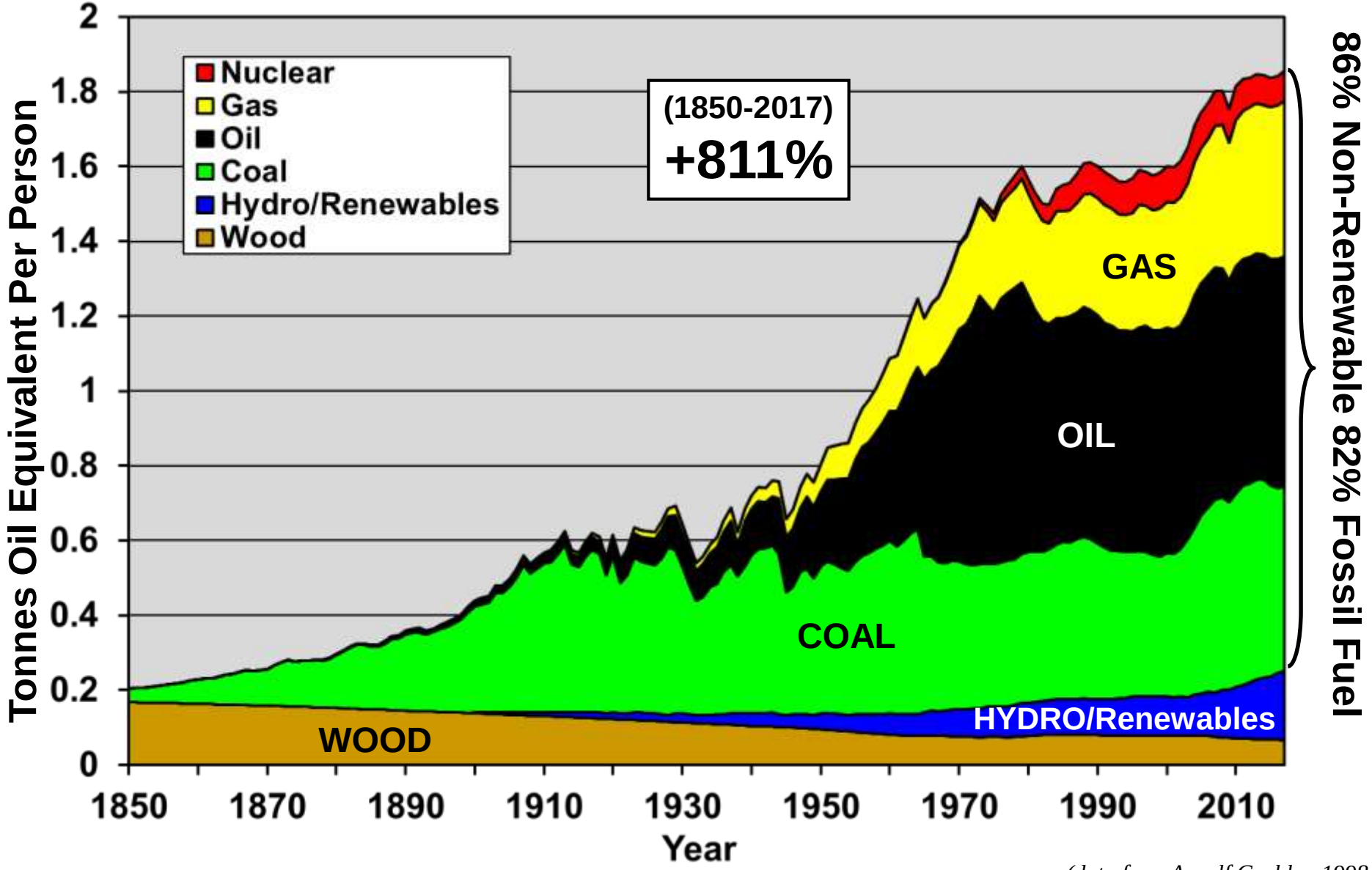
- ***Implications for the path forward***

Total World Energy Consumption Rate, 1850-2017, as a Percentage of 2017 Levels



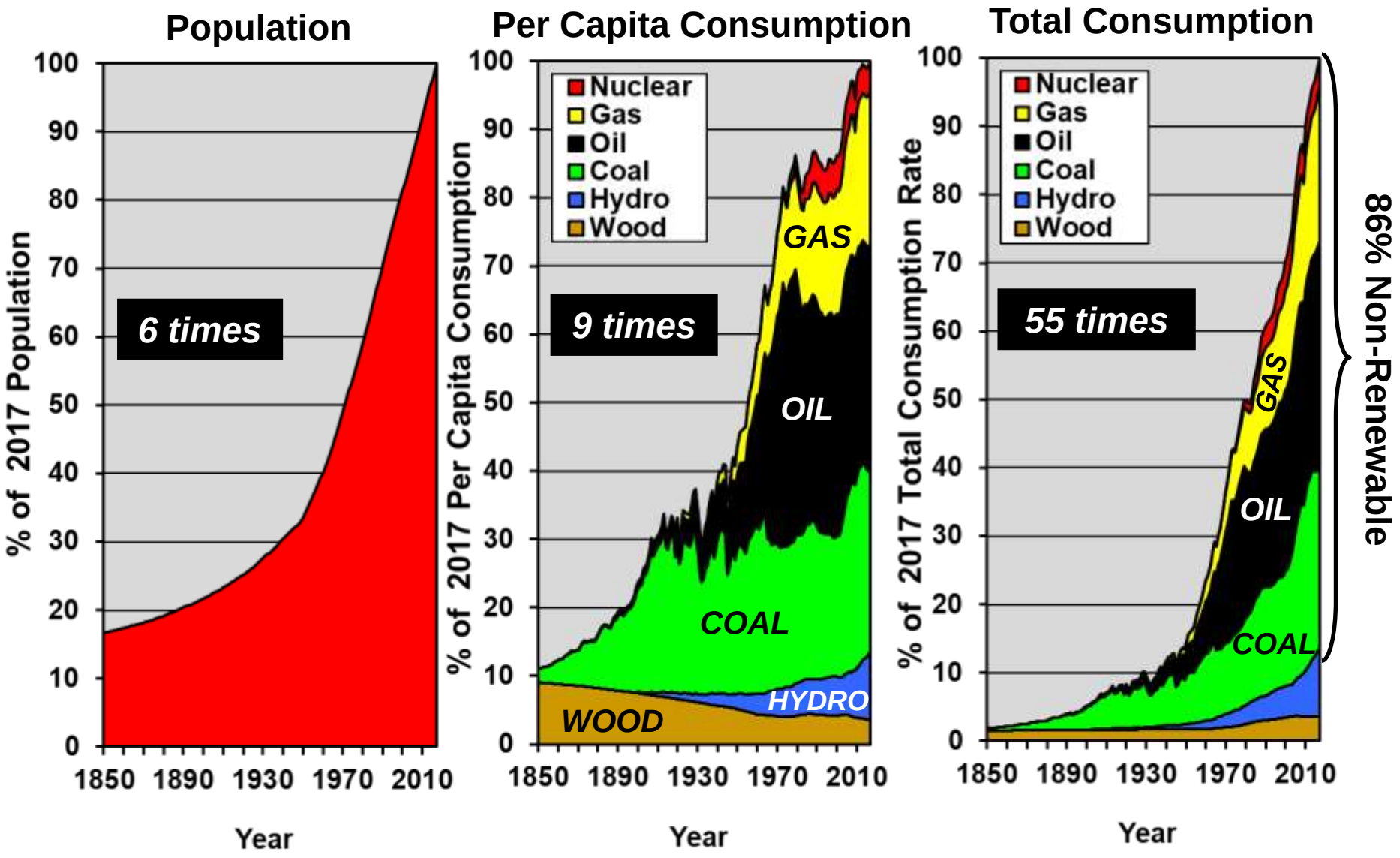
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018)

World Per Capita Annual Primary Energy Consumption by Fuel 1850-2017



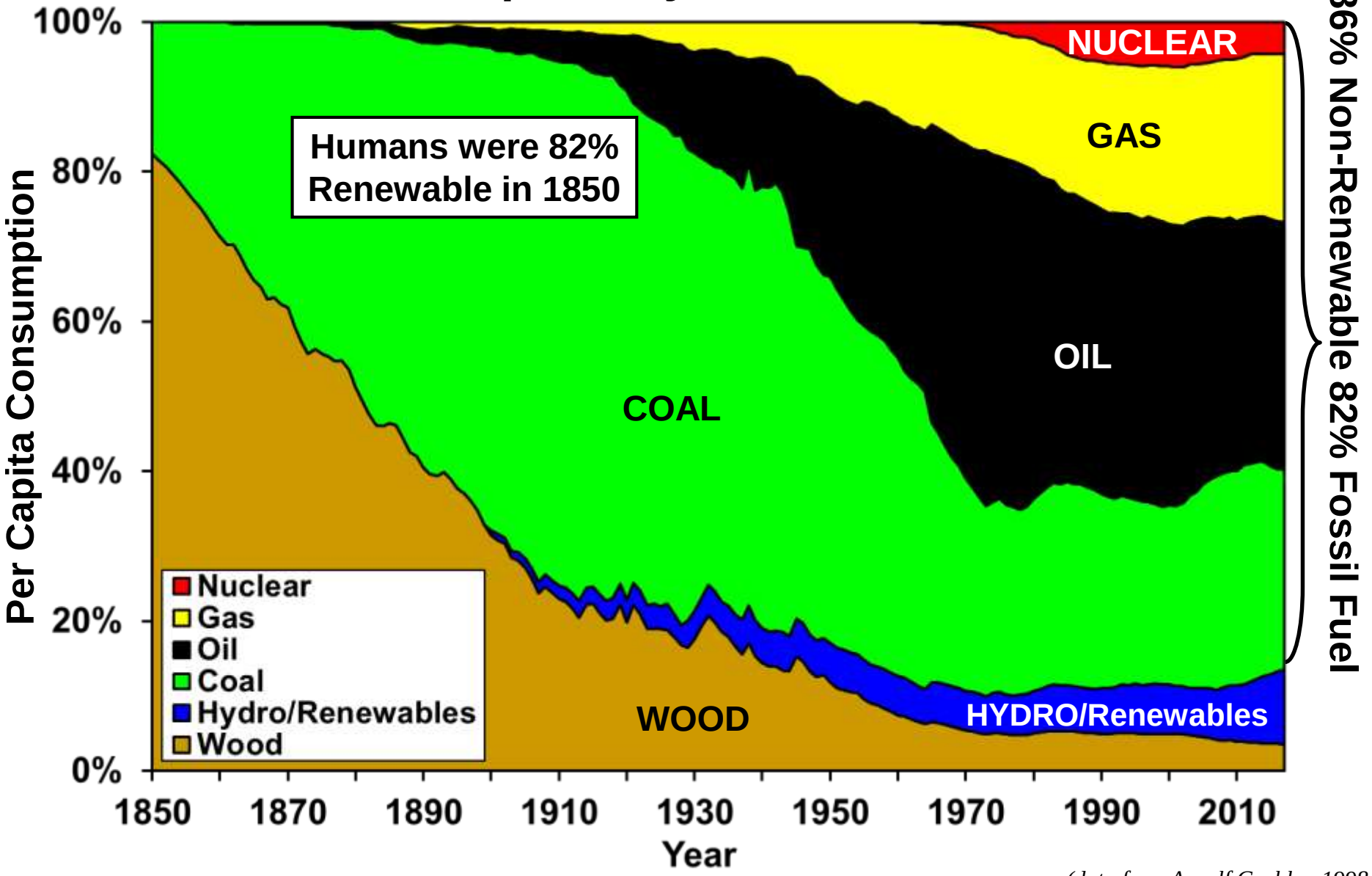
(data from Arnulf Grubler, 1998;
BP Statistical Review of World Energy, 2018; UN and historical population data)

World Population, Per Capita and Total Energy Consumption, 1850-2017, as a Percentage of 2017 Levels



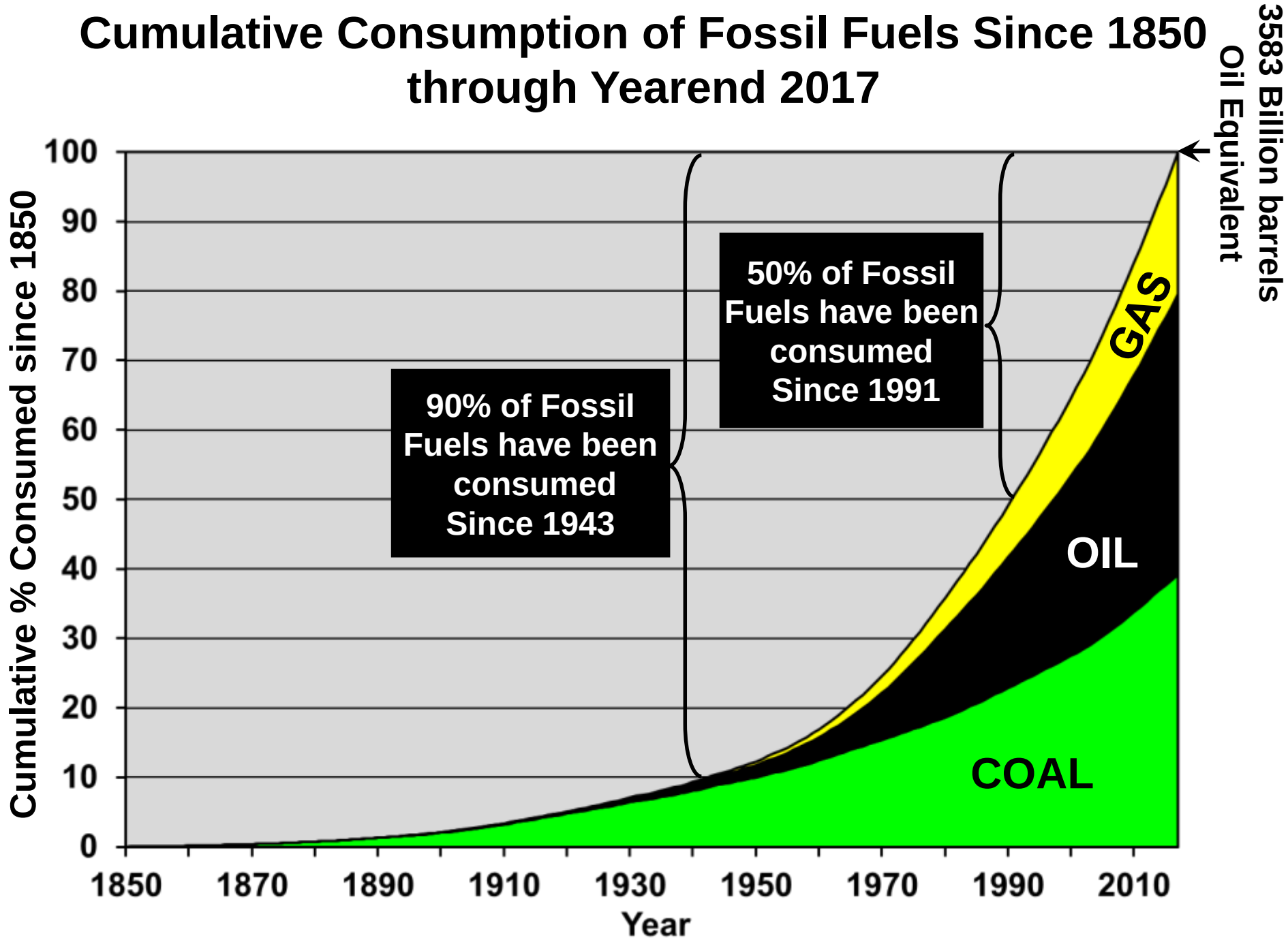
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018; UN Population Bureau, 2019)

World Per Capita Annual Primary Energy Consumption by Fuel 1850-2017



(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018; UN and historical populations data)

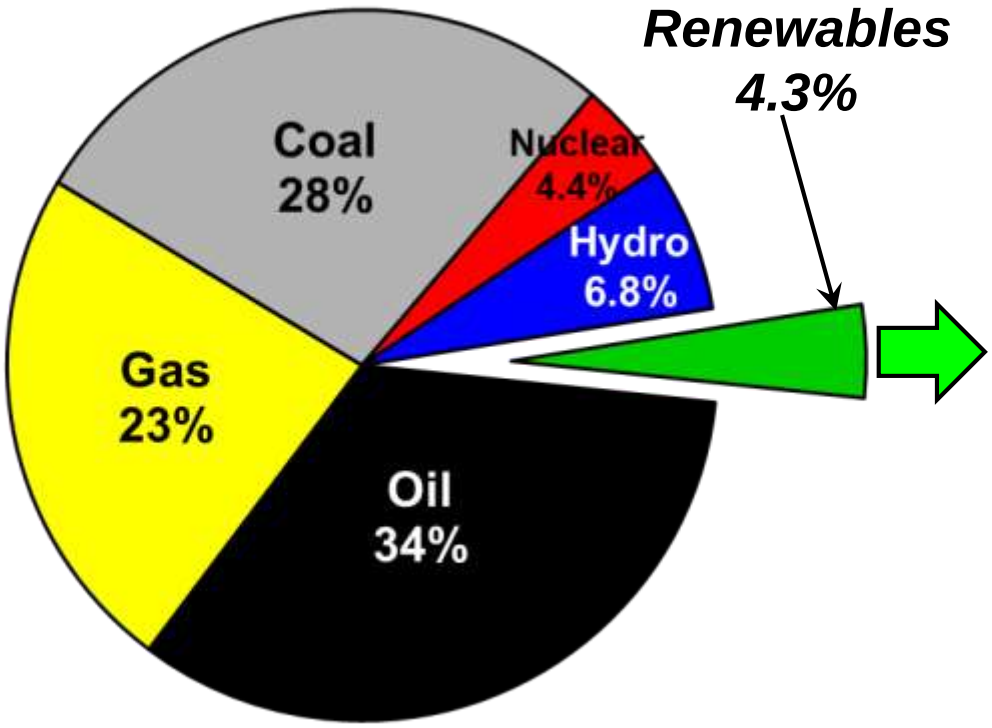
Cumulative Consumption of Fossil Fuels Since 1850 through Yearend 2017



(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018)

Global Primary Energy Consumption by Source in 2017
A Comparison to Total Non-Hydro Renewable* Energy

Total Energy by Source
13512 MTOE

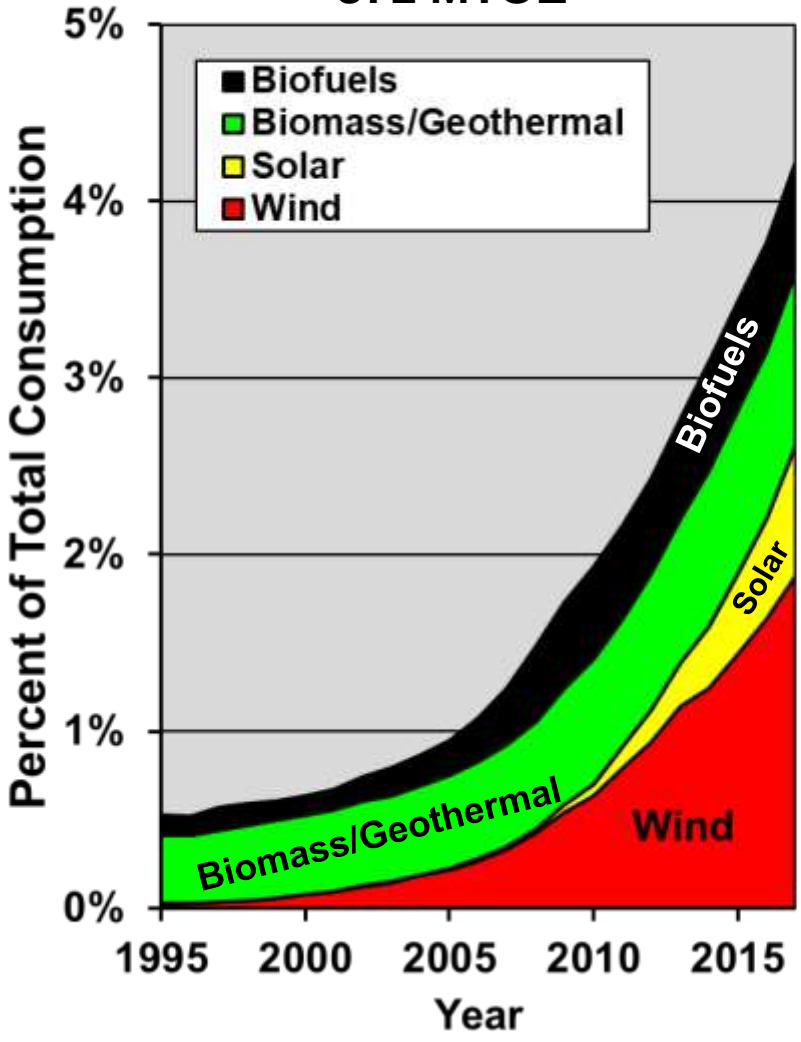


Large Hydro plus Renewables = 11.1%

Total consumption has increased by 59% more than all 2017 non-hydro renewables since 2010

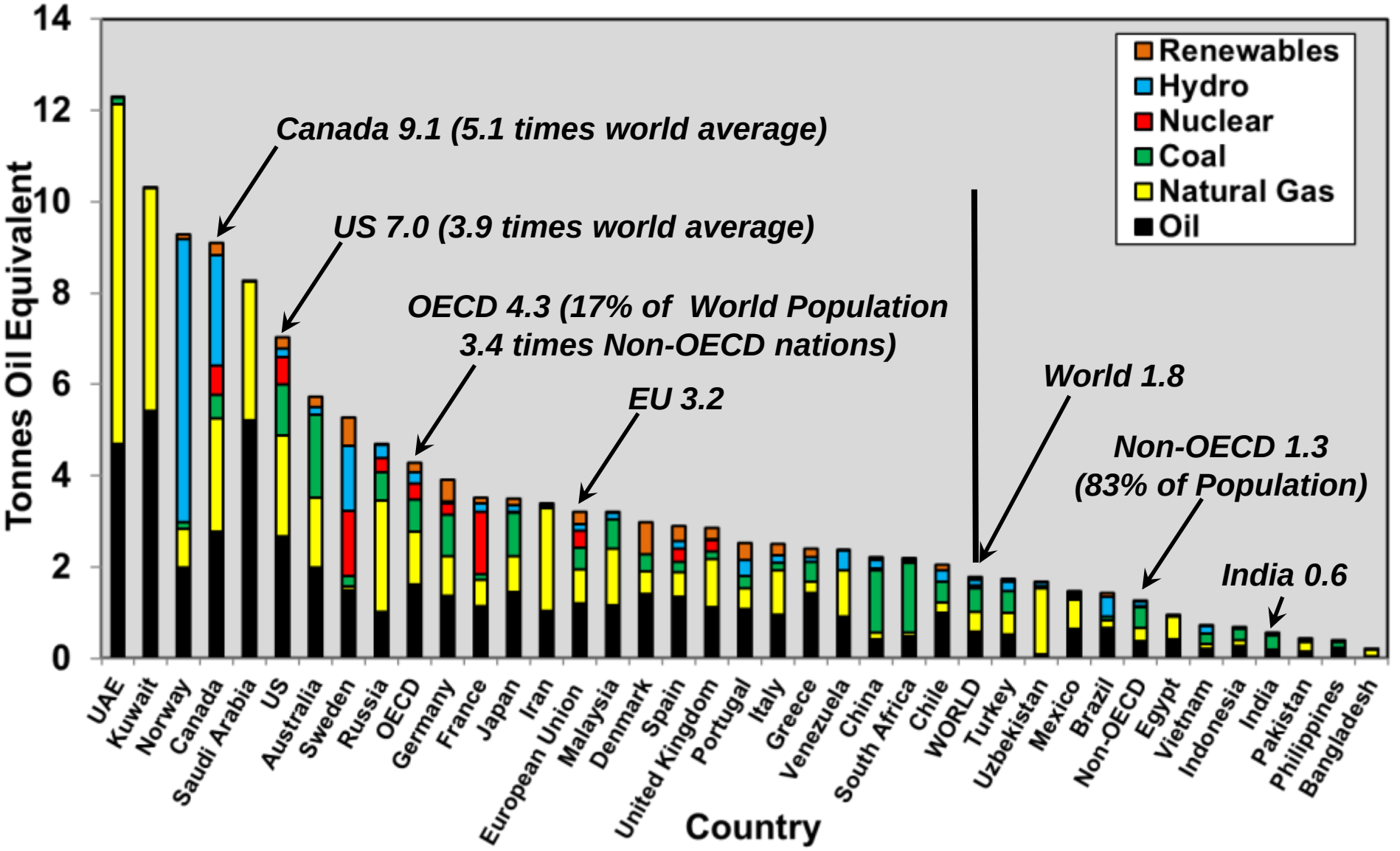
***excluding traditional biomass estimated at 7.8% in 2017**

Renewable Energy by Source
571 MTOE



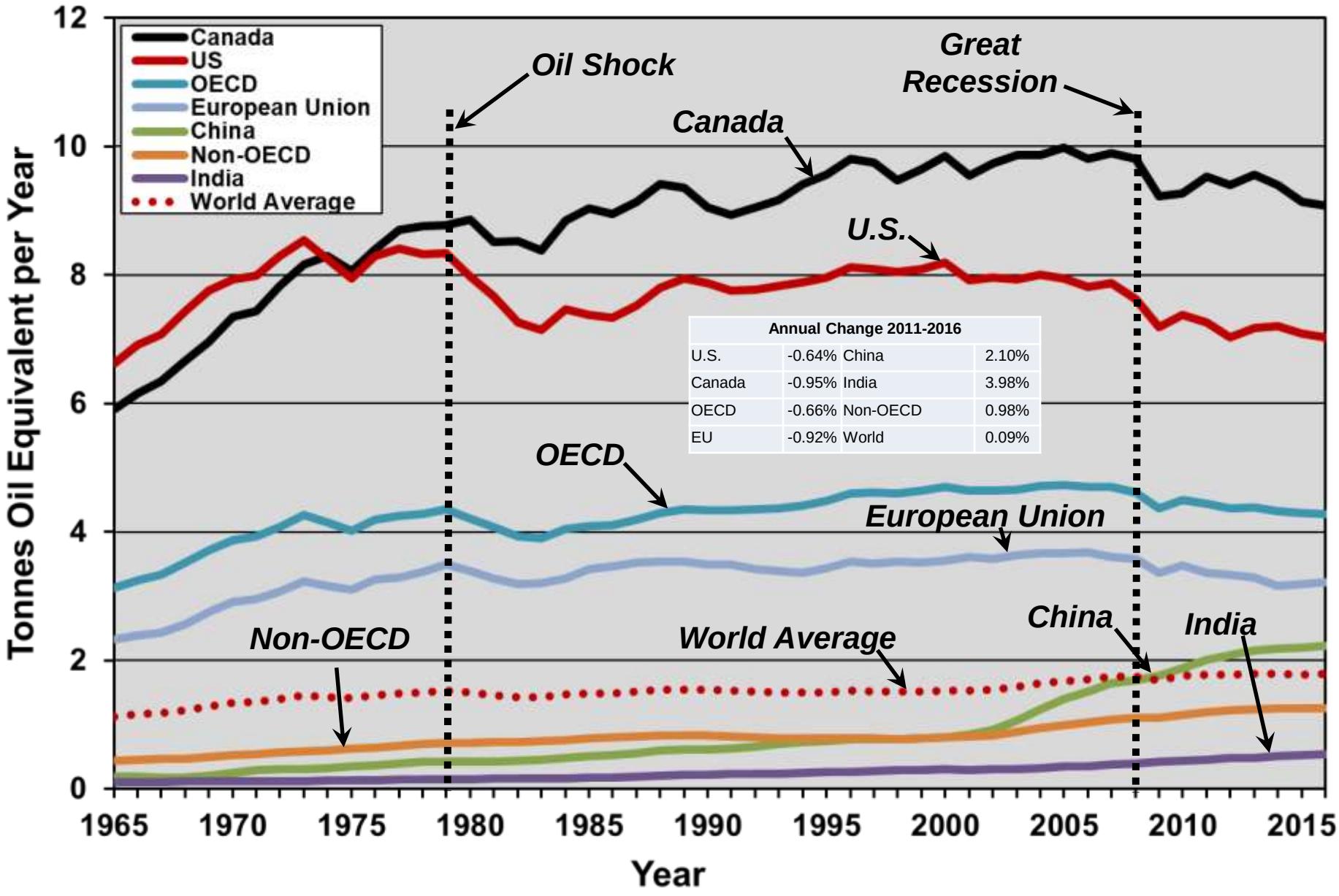
(data from BP Statistical Review of World Energy, 2018; traditional biomass from REN21, 2019)

Per Capita Consumption of Primary Energy by Fuel and Country in 2016



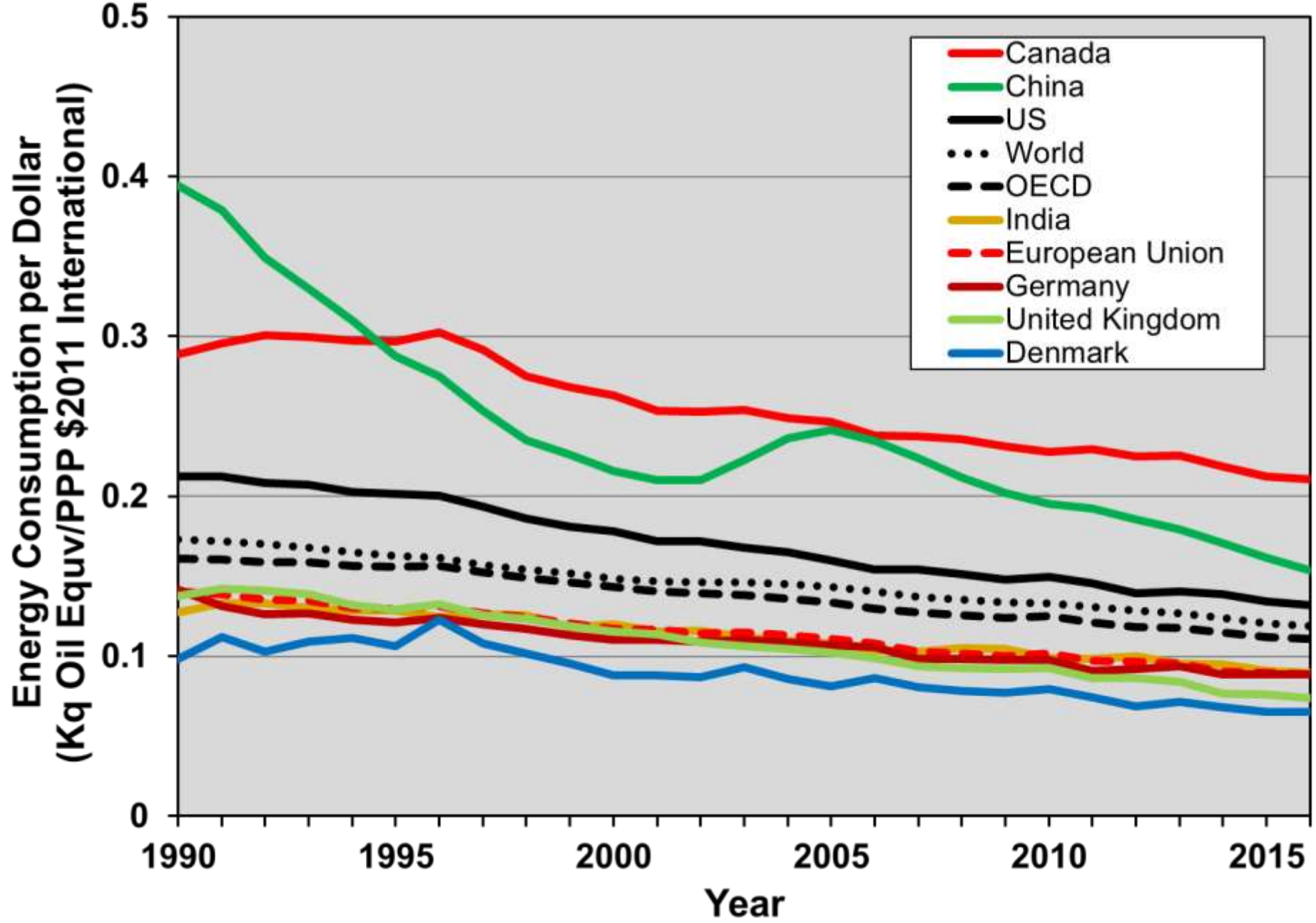
(data from BP Statistical Review 2017 and World Bank population statistics for 2016)

Per Capita Energy Consumption by Country, 1965-2016



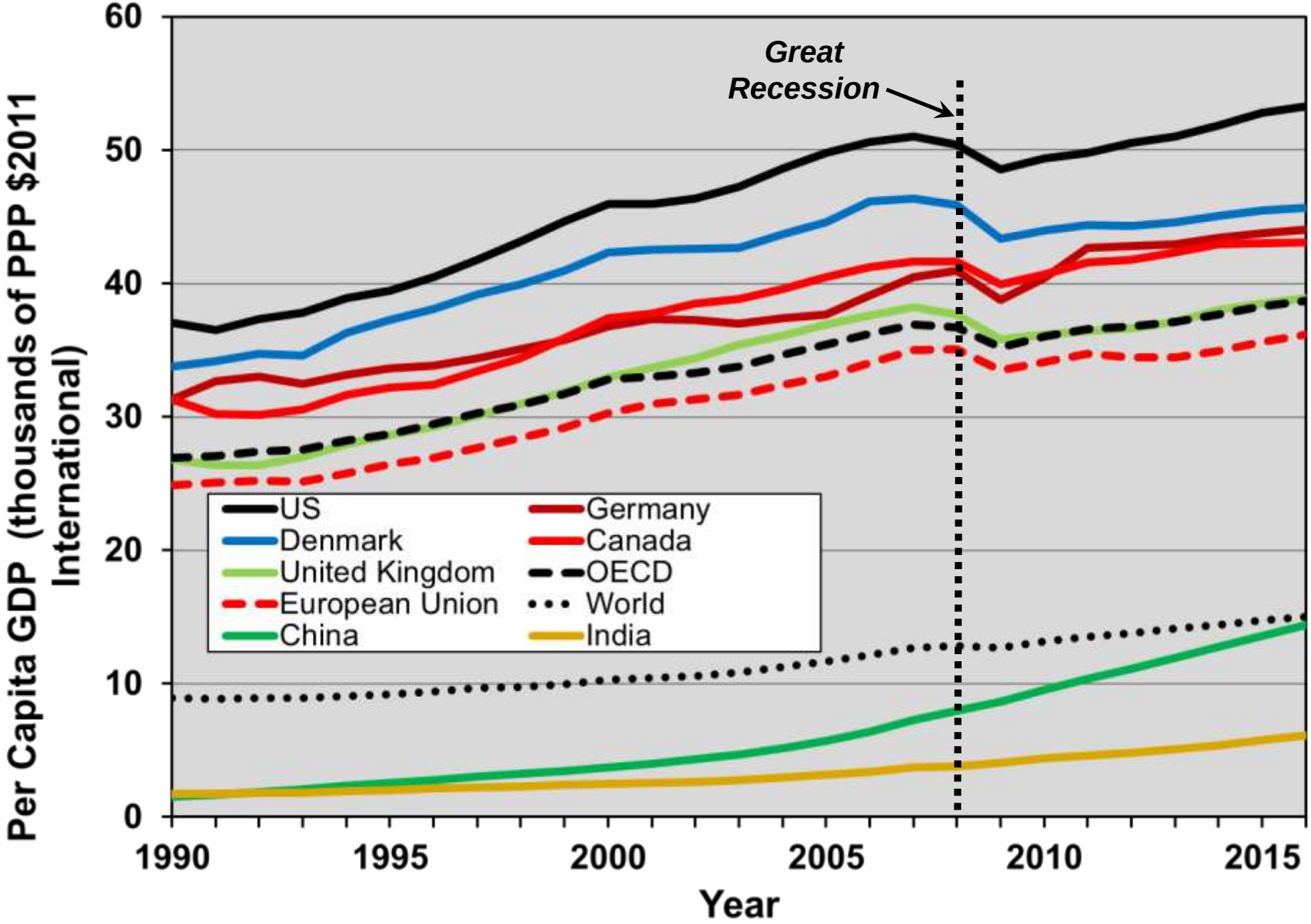
(data from BP Statistical Review 2017 and World Bank population statistics)

Energy Consumption per Dollar of GDP, 1990-2016



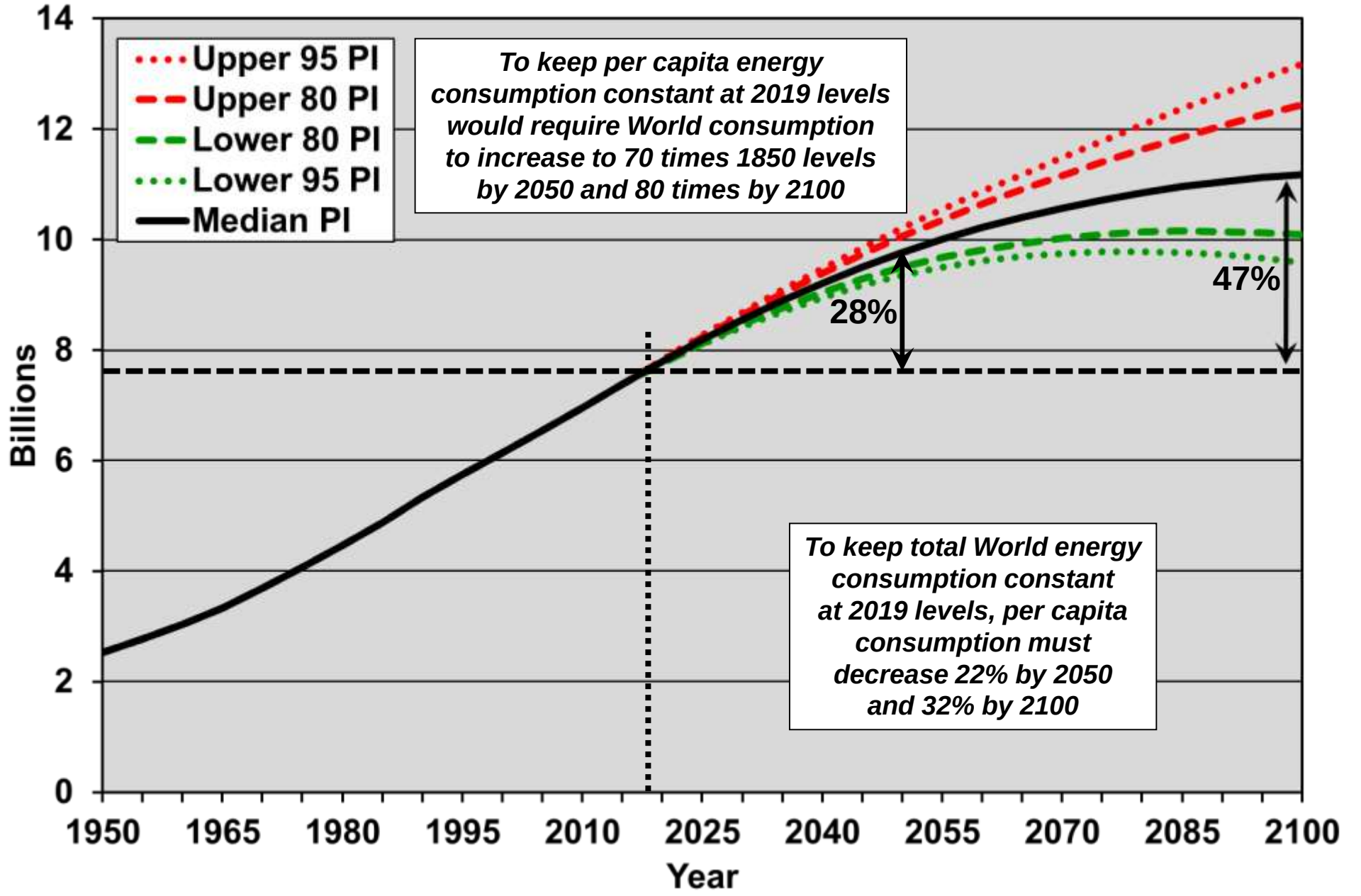
(GDP data from World Bank, 2017; Energy consumption from BP Statistical Review, 2017)

Per Capita GDP by Country 1990-2016



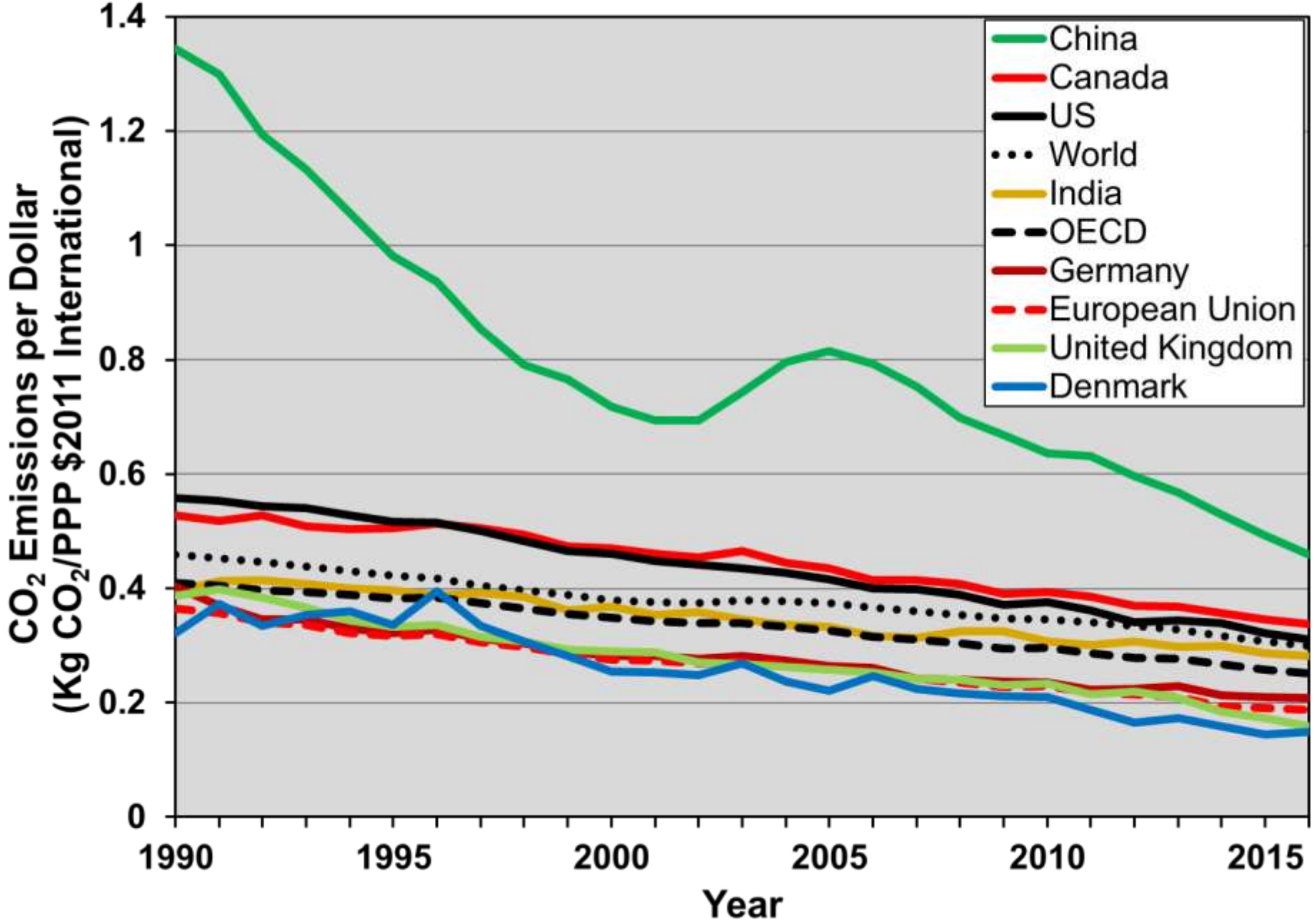
(per capita GDP data from World Bank, 2017)

United Nations World Population Projections through 2100



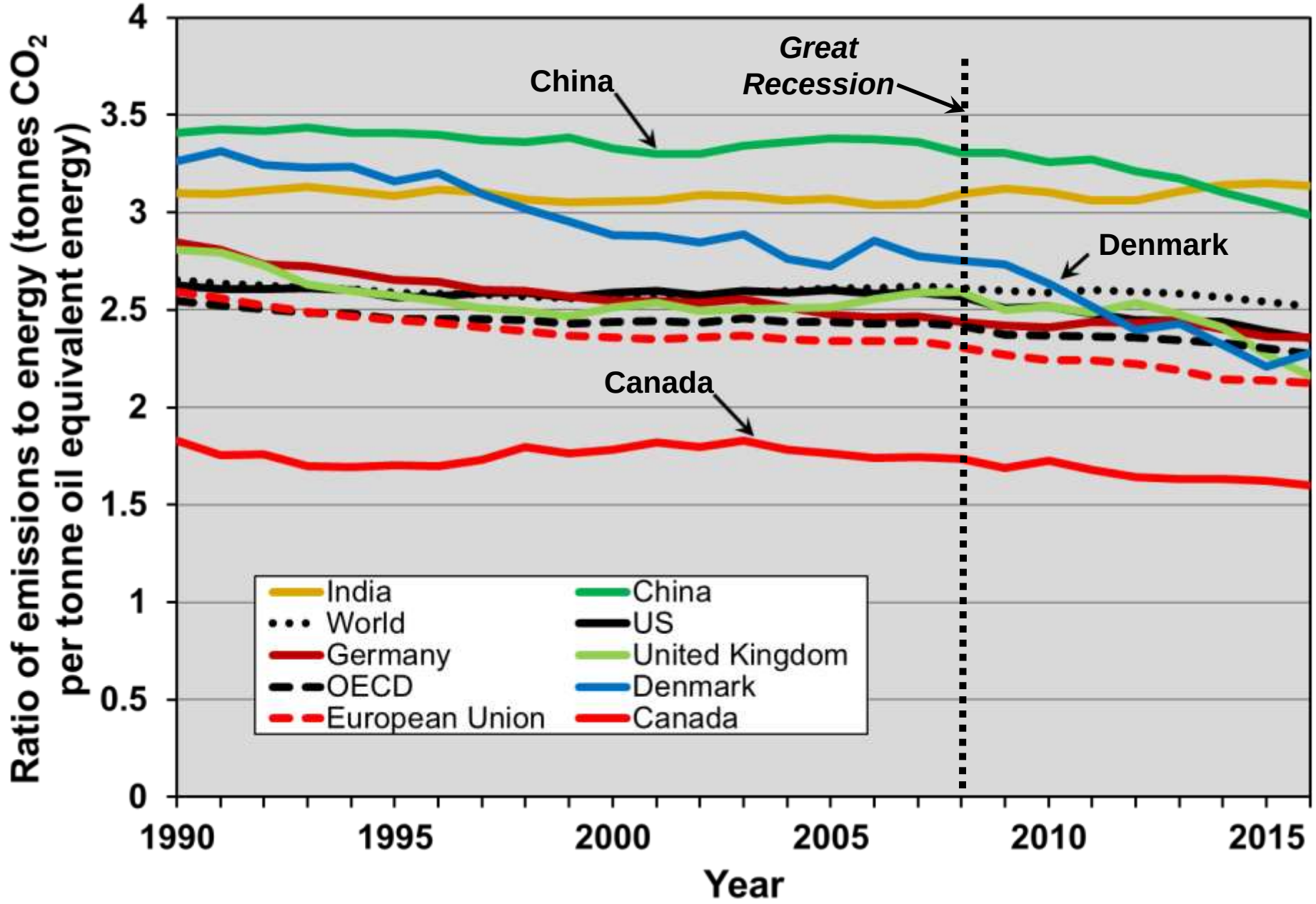
(United Nations World Population Prospects: The 2017 Edition)

Emissions Intensity – CO_2 emissions per Dollar of GDP



(GDP data from World Bank, 2017; CO2 Emissions from BP Statistical Review, 2017)

Ratio of CO_2 Emissions to Energy Consumption, 1990-2016



(CO_2 emissions from fossil fuels only; data from BP Statistical Review, 2017)

2018:

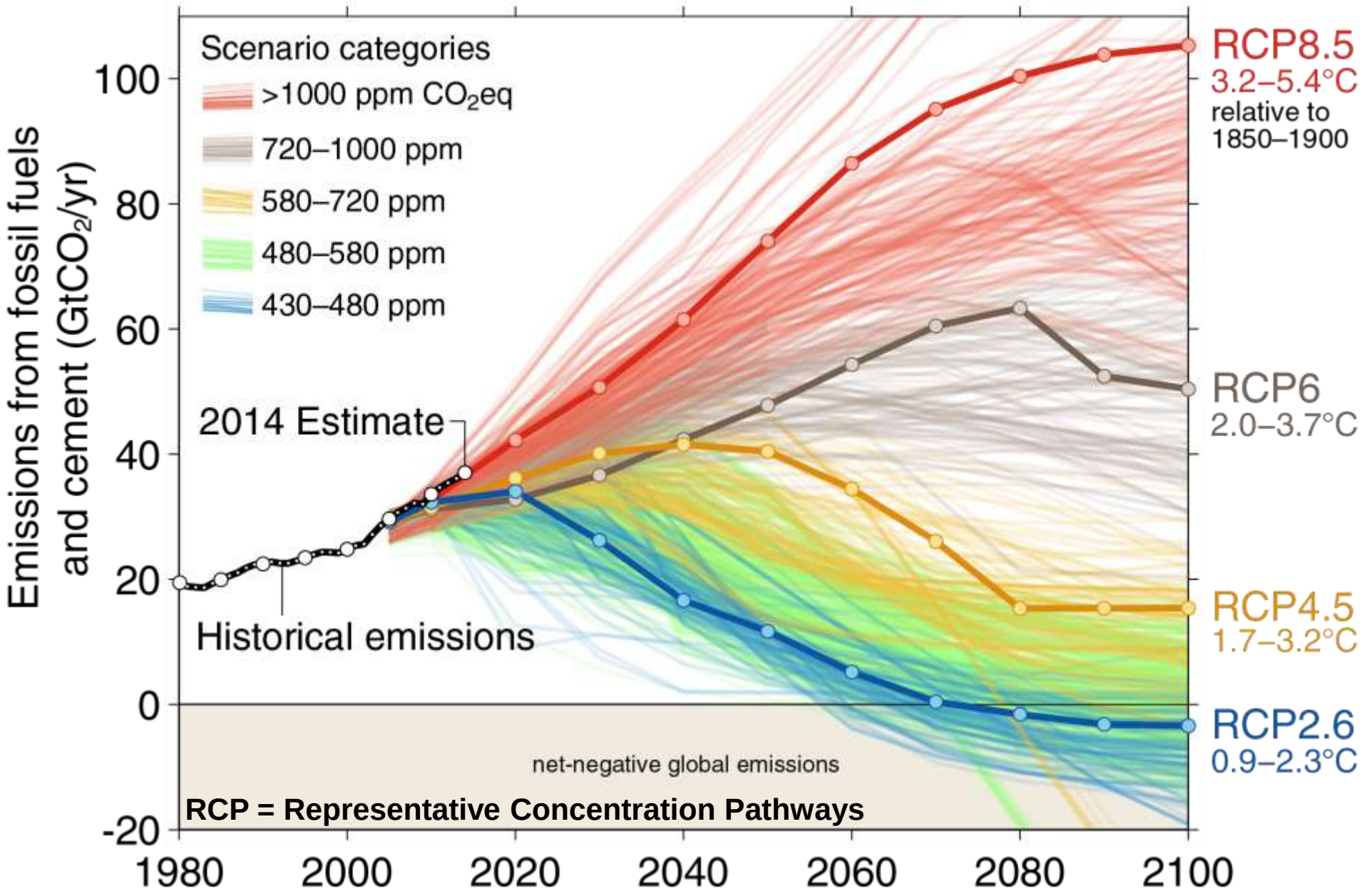
- *4th hottest year on record*

- *record consumption of fossil fuels*

- *record level of emissions*

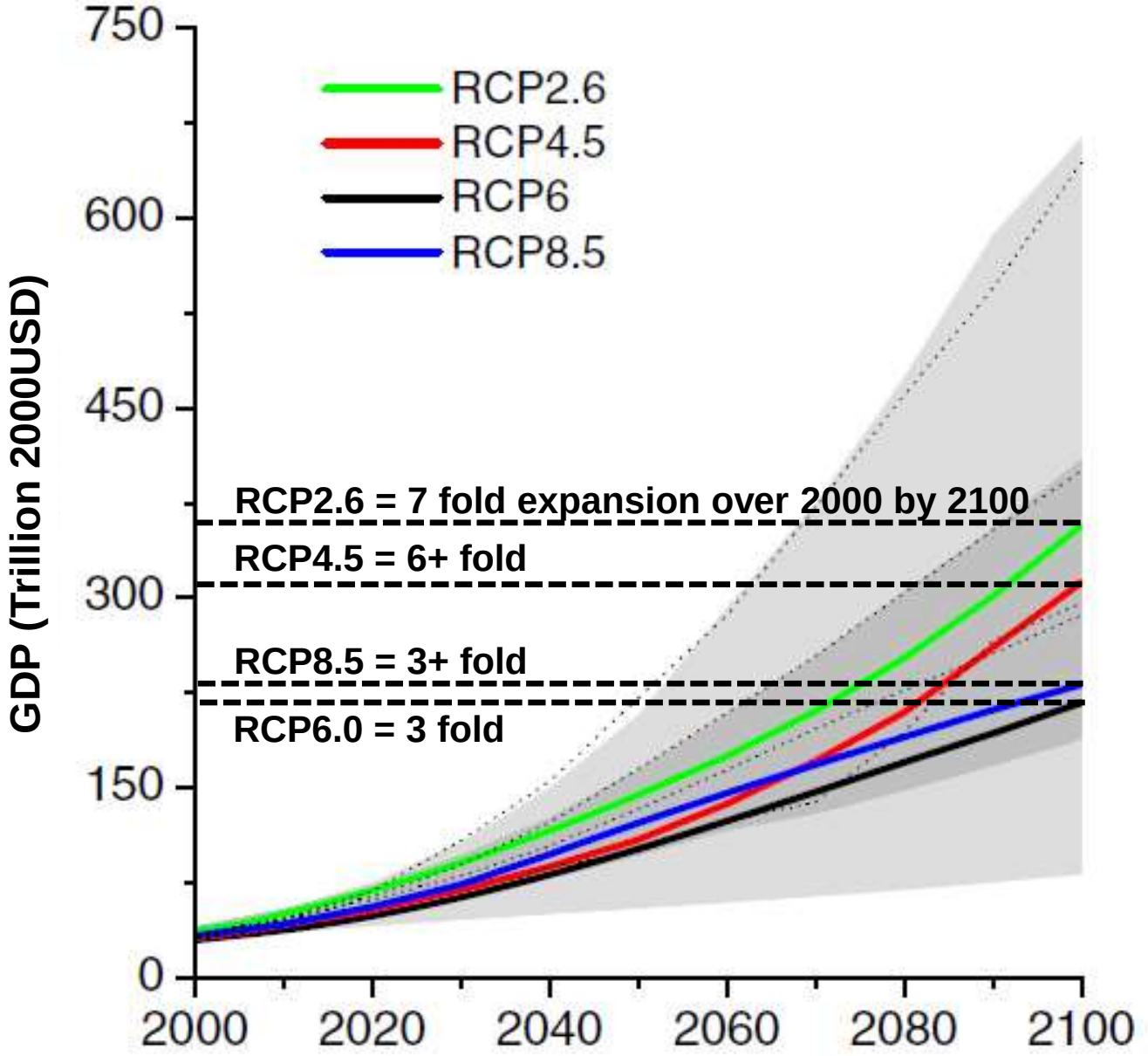
- *24th COP UN conference on climate change on doing something about it*

IPCC RCP Scenario Carbon Dioxide Emissions



(Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014)

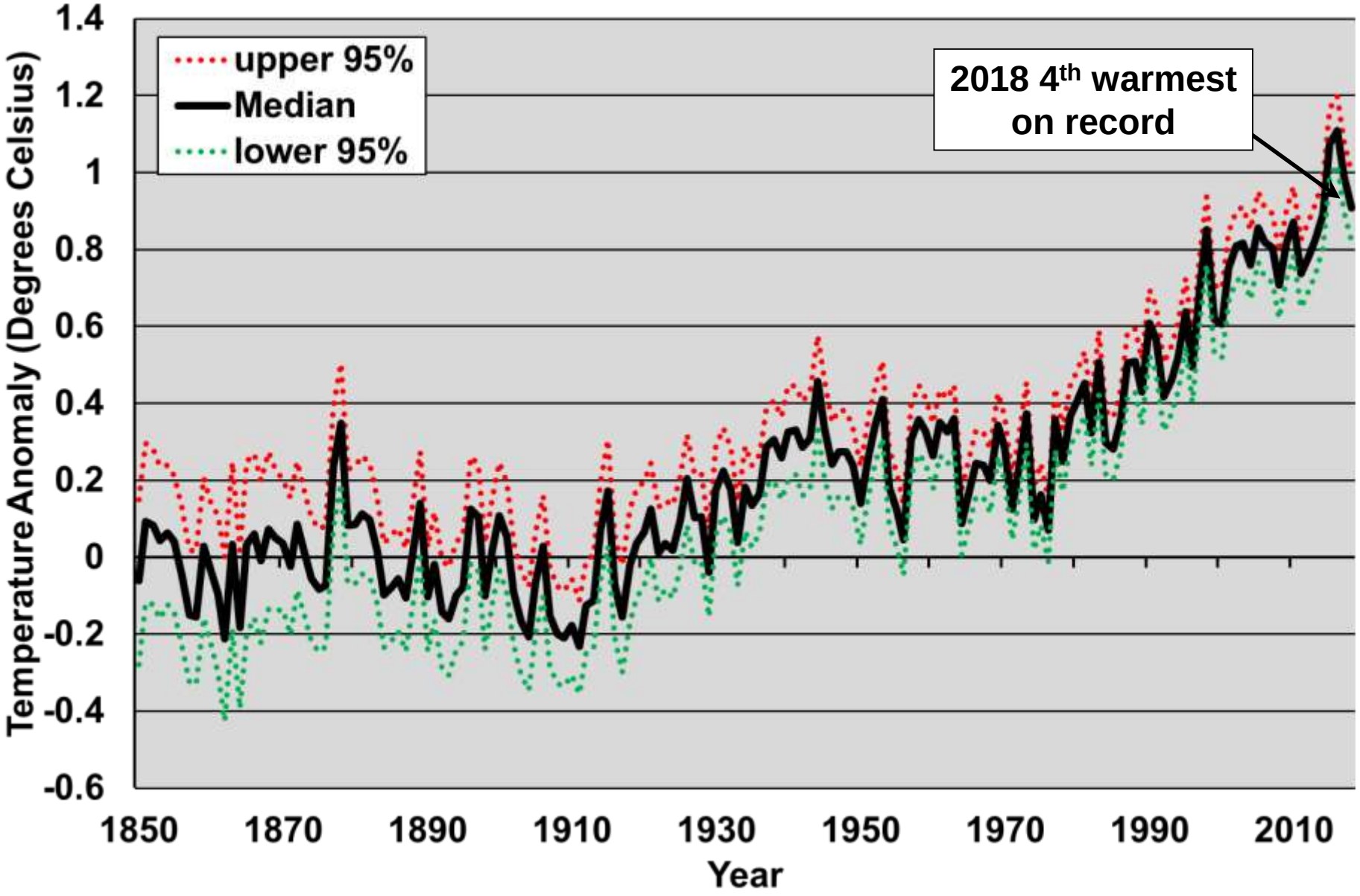
IPCC GDP Growth Assumptions by RCP Scenario



(Modified from van Vuuren et al., 2011, Climatic Change 109:5-31)

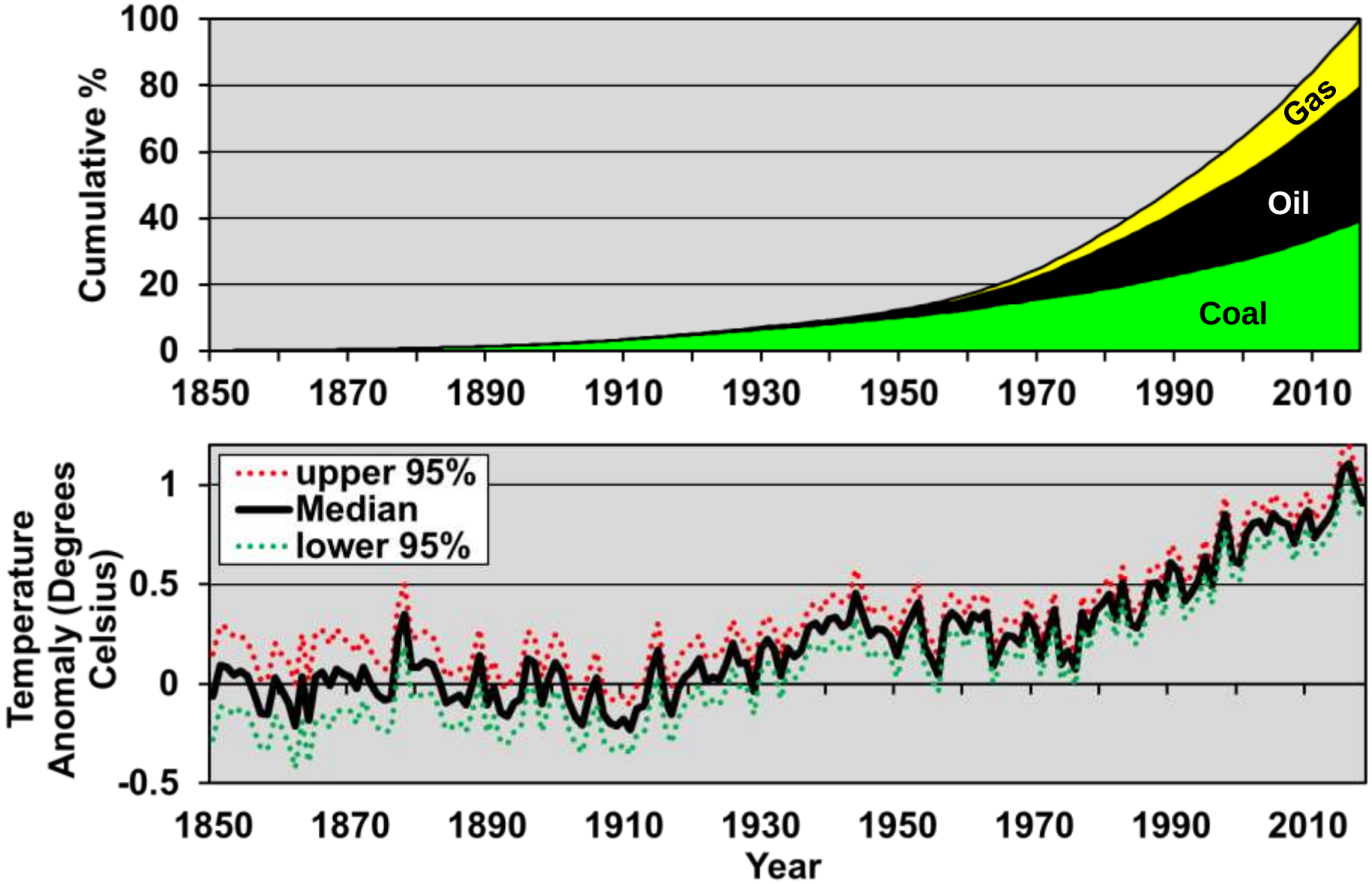
Given the correlation of energy and growth:

Global Temperature Anomaly 1850-2018 relative to an 1850-1900 Baseline



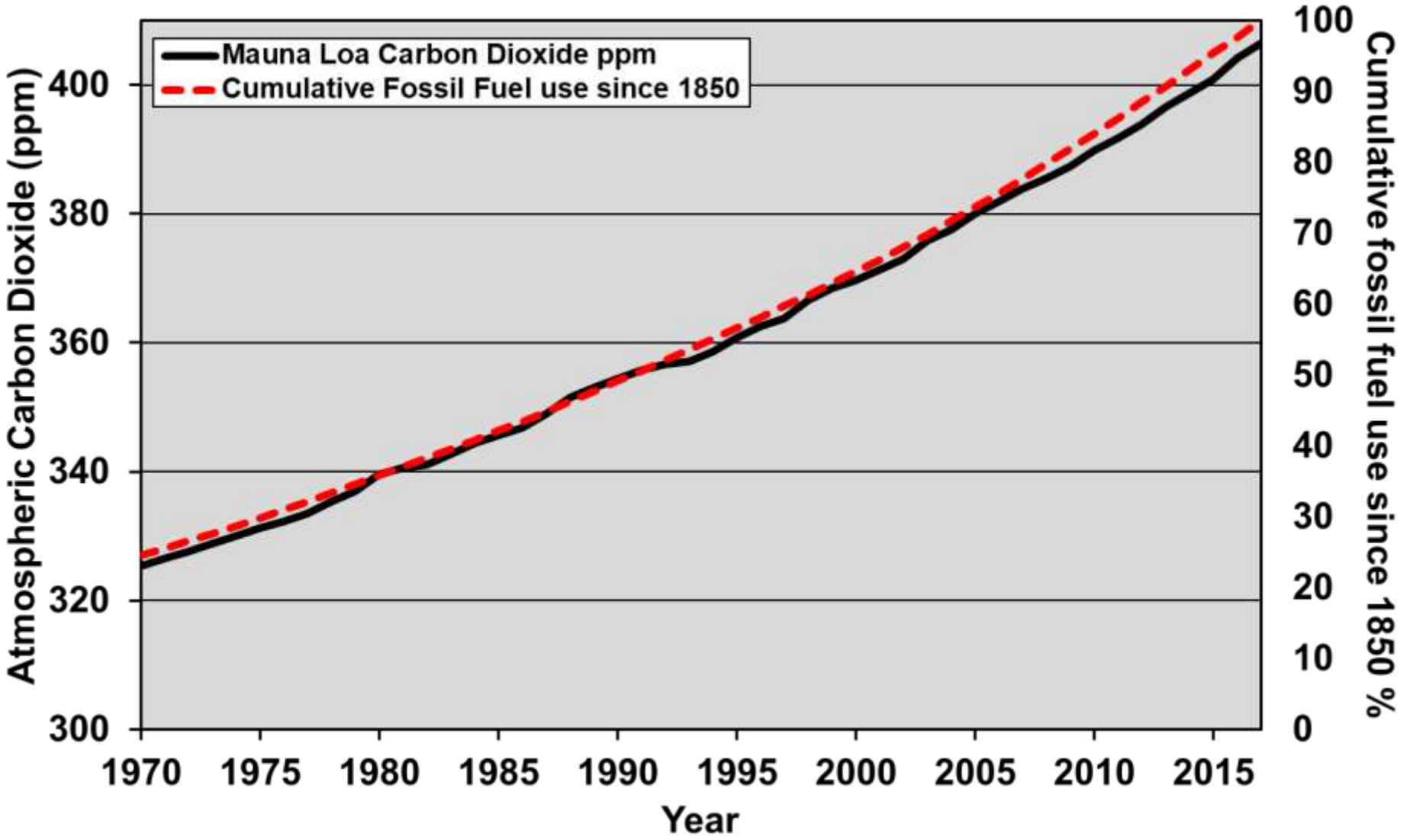
(Hadcrut 4 Global annual data retrieved February, 2019)

Global Temperature Anomaly 1850-2018
Compared to Cumulative Fossil Fuel Consumption



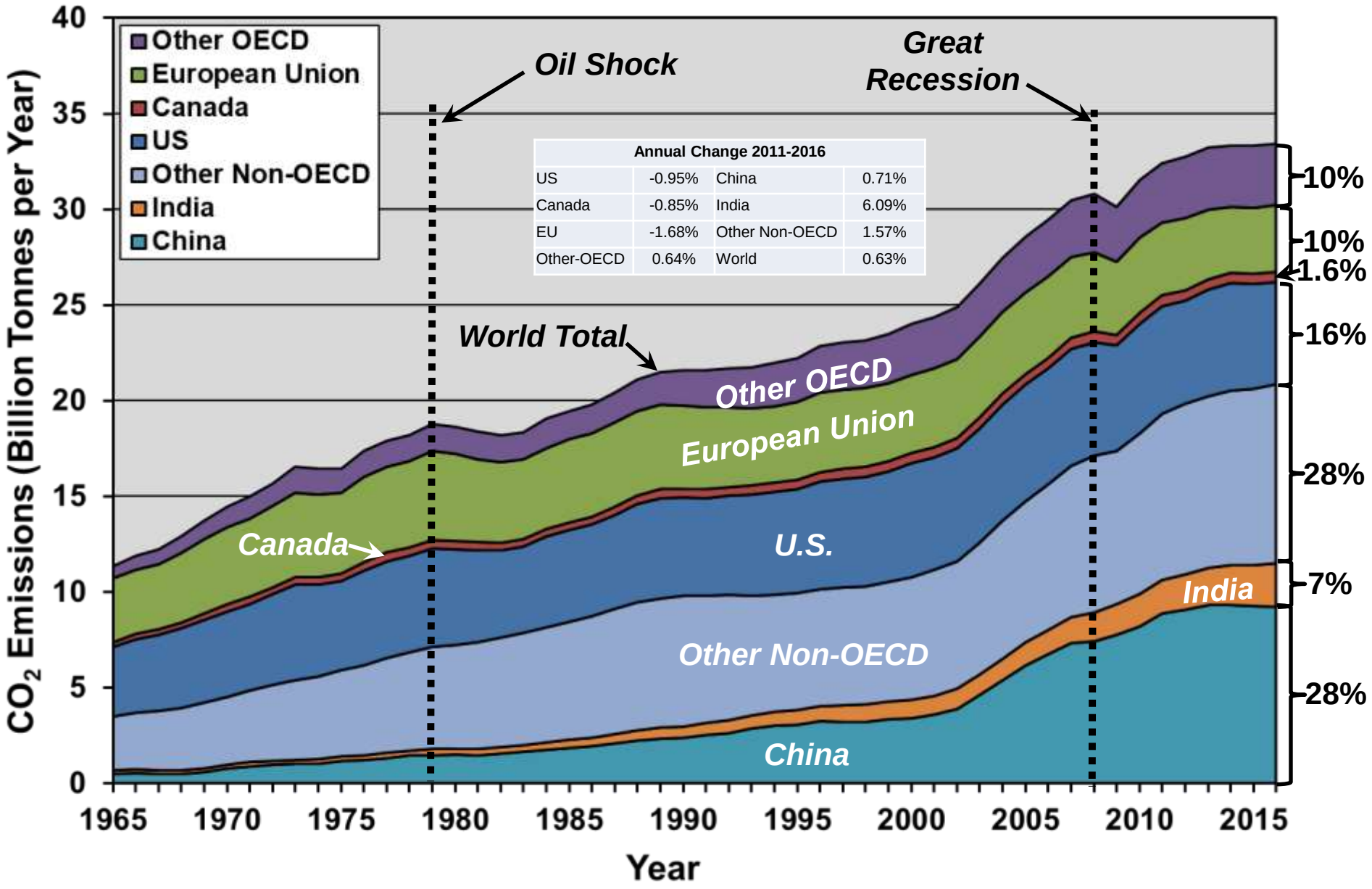
(Arnulf Grubler 1998, BP 2018 and Hadcrut 4 Global annual data retrieved February, 2019)

Mauna Loa Carbon Dioxide Measurements, 1970-2017, Versus Cumulative Consumption of Fossil Fuel since 1850



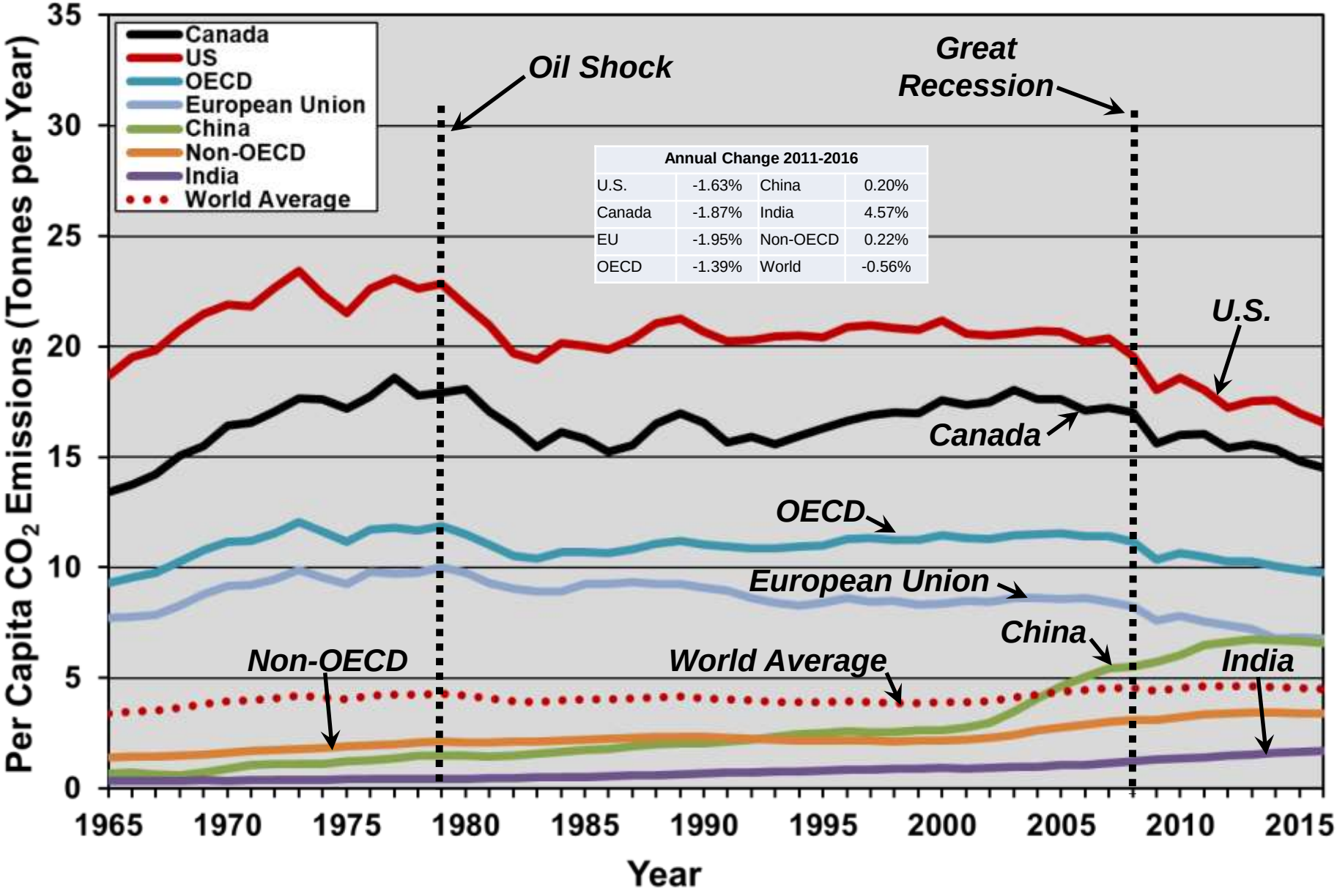
(Arnulf Grubler 1998, BP 2018, NOAA Earth System Research Laboratory and Hadcrut 4 Global annual data retrieved February, 2019)

Total Fossil Fuel CO_2 Emissions by Country, 1965-2016



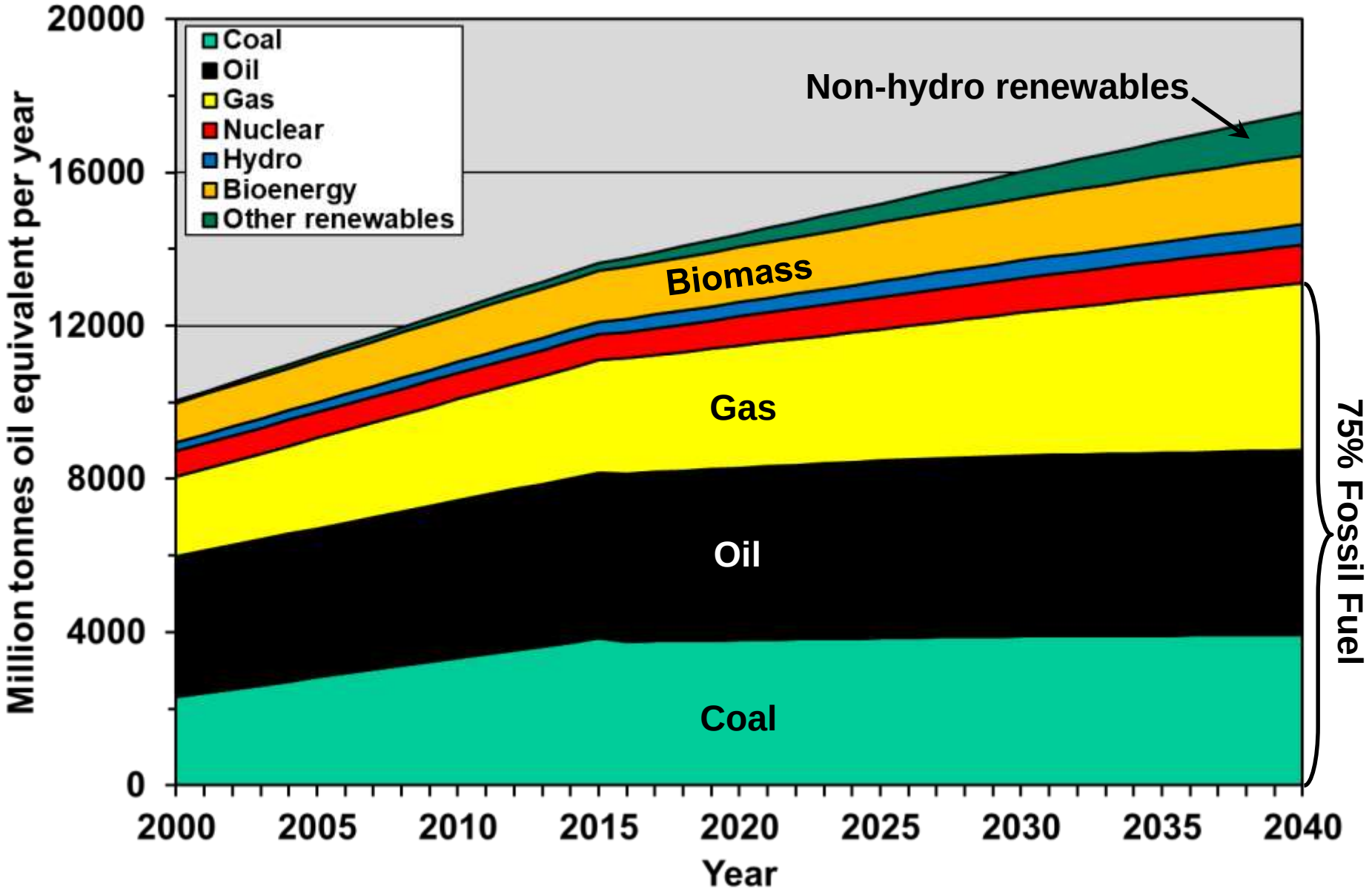
(data from BP Statistical Review 2017)

Per Capita CO_2 Emissions by Country, 1965-2016



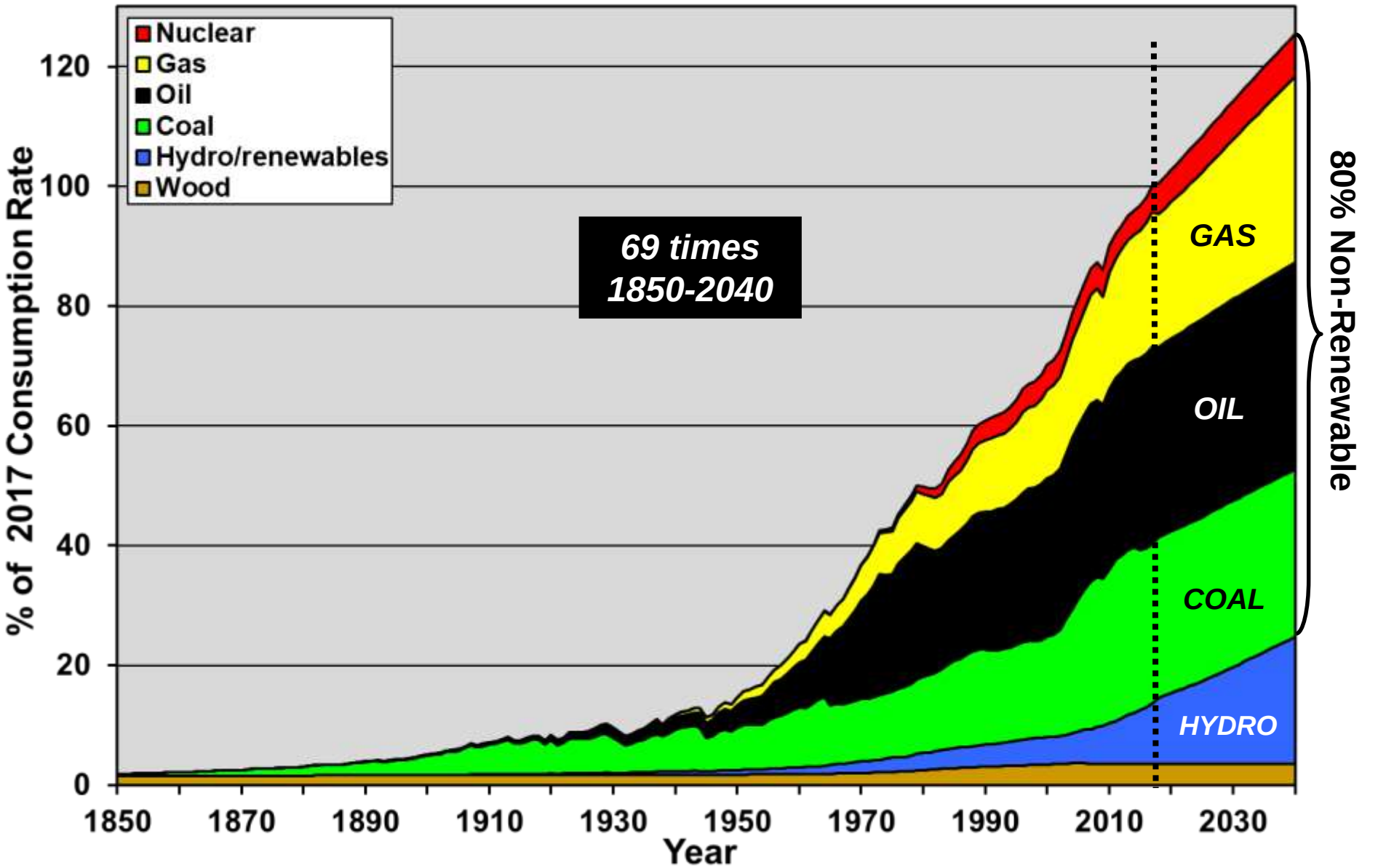
(data from BP Statistical Review 2017 and World Bank population statistics)

International Energy Agency *New Policies Scenario* Projections of Primary Energy by Fuel, through 2040



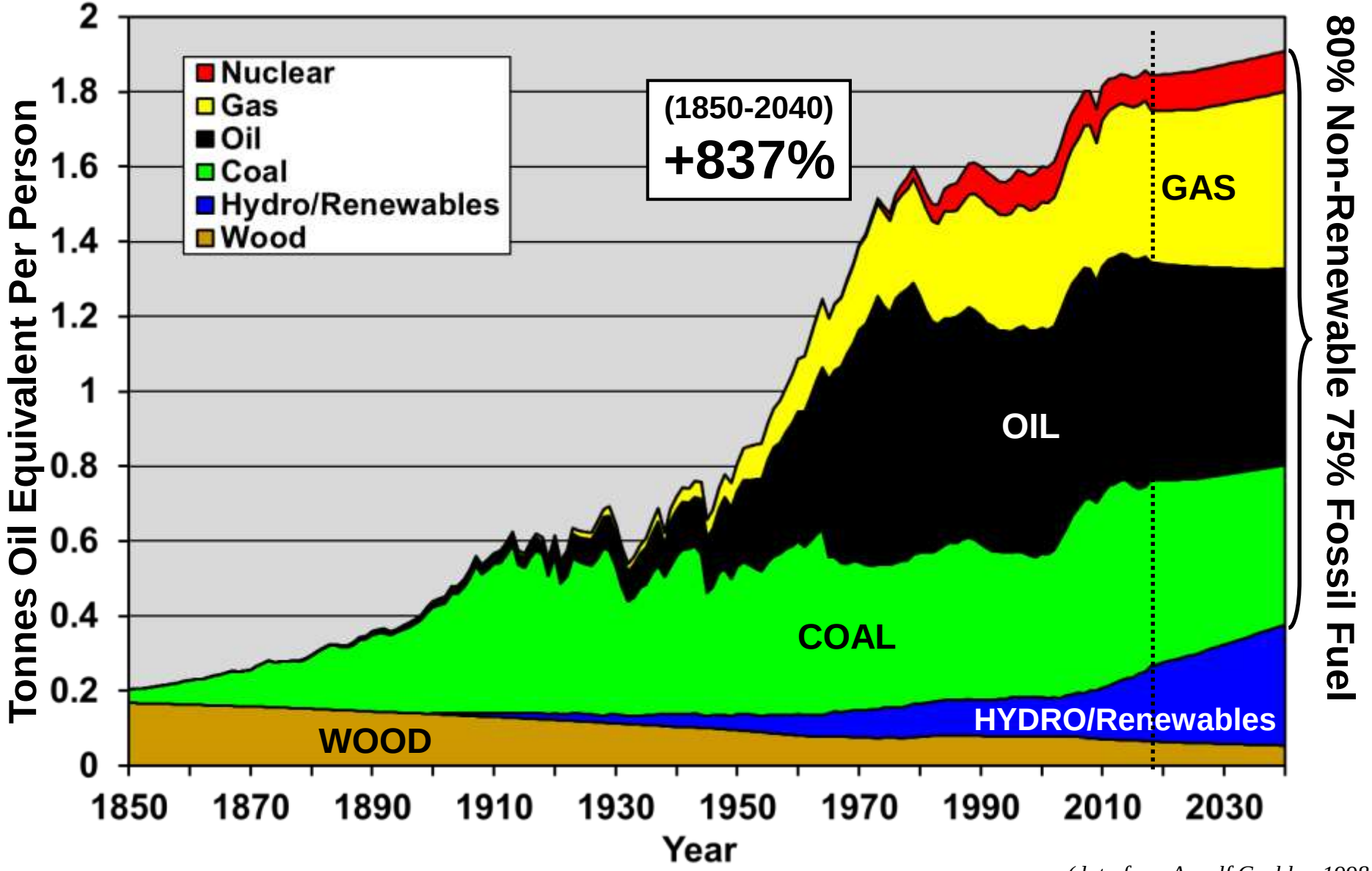
(International Energy Agency World Energy Outlook 2017, New Policies Scenario)

Total Energy Consumption Rate, 1850-2040, as a Percentage of 2017 Levels with IEA *New Policies Scenario*



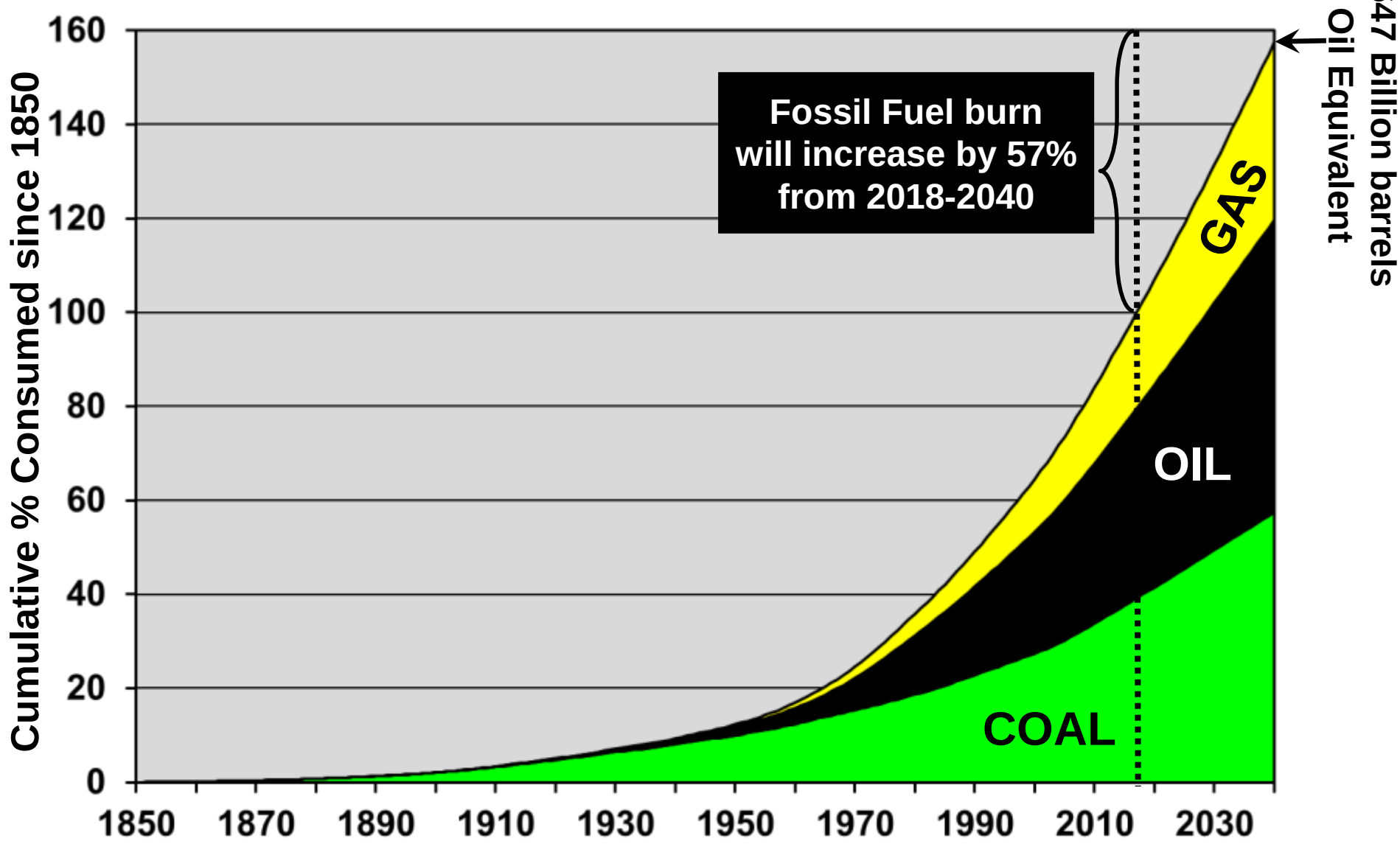
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018; IEA NPS scenario, 2017)

World Per Capita Annual Primary Energy Consumption by Fuel 1850-2040 IEA *New Policies Scenario*



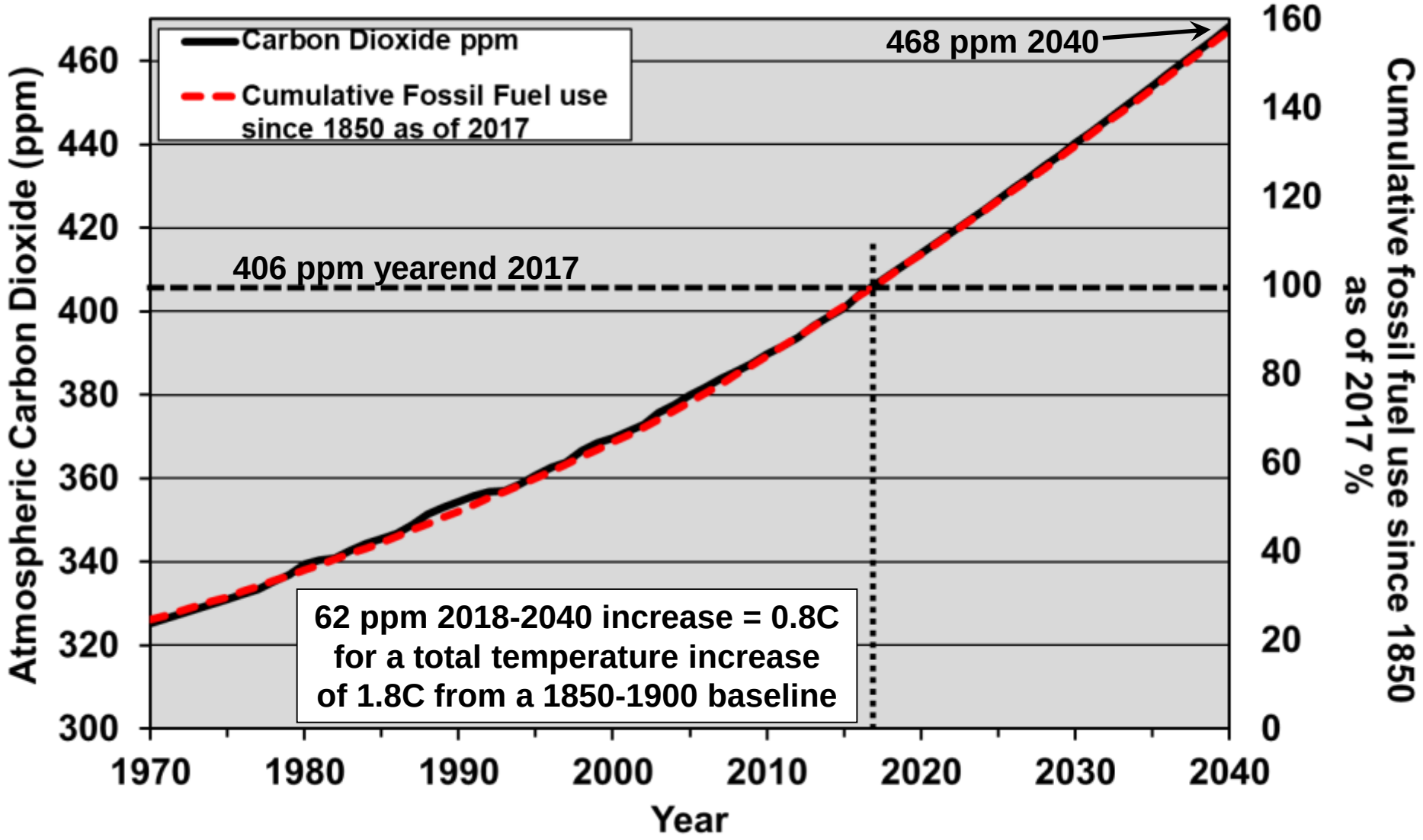
(data from Arnulf Grubler, 1998;
BP Statistical Review of World Energy, 2018; UN and historical population data)

Cumulative Consumption of Fossil Fuels Since 1850 through Yearend 2040 with IEA *New Policies Scenario*



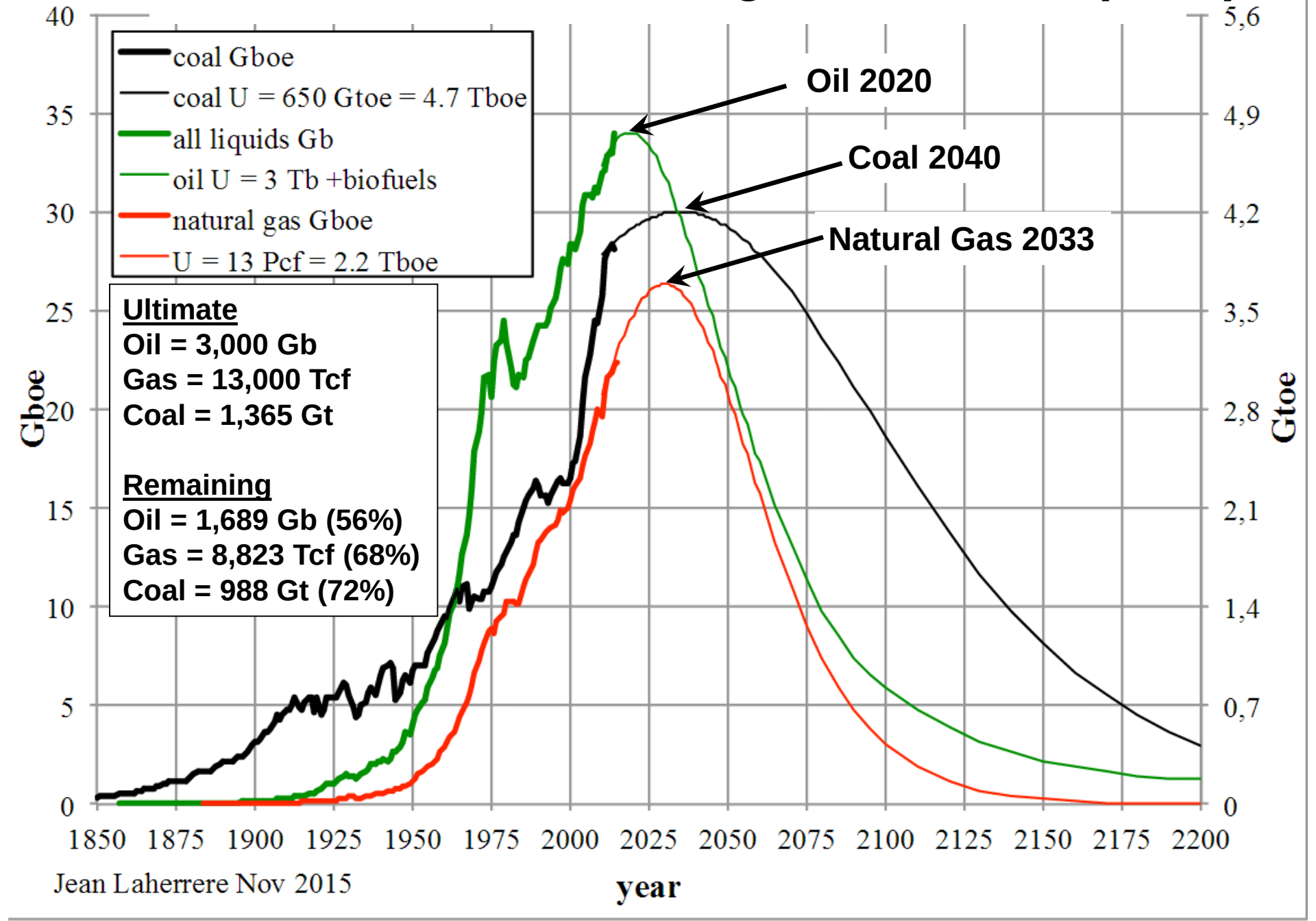
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2018; IEA NPS Scenario, WEO 2017)

Atmospheric Carbon Dioxide Projection to 2040 with IEA New Policies Scenario vs Fossil fuel use since 1850

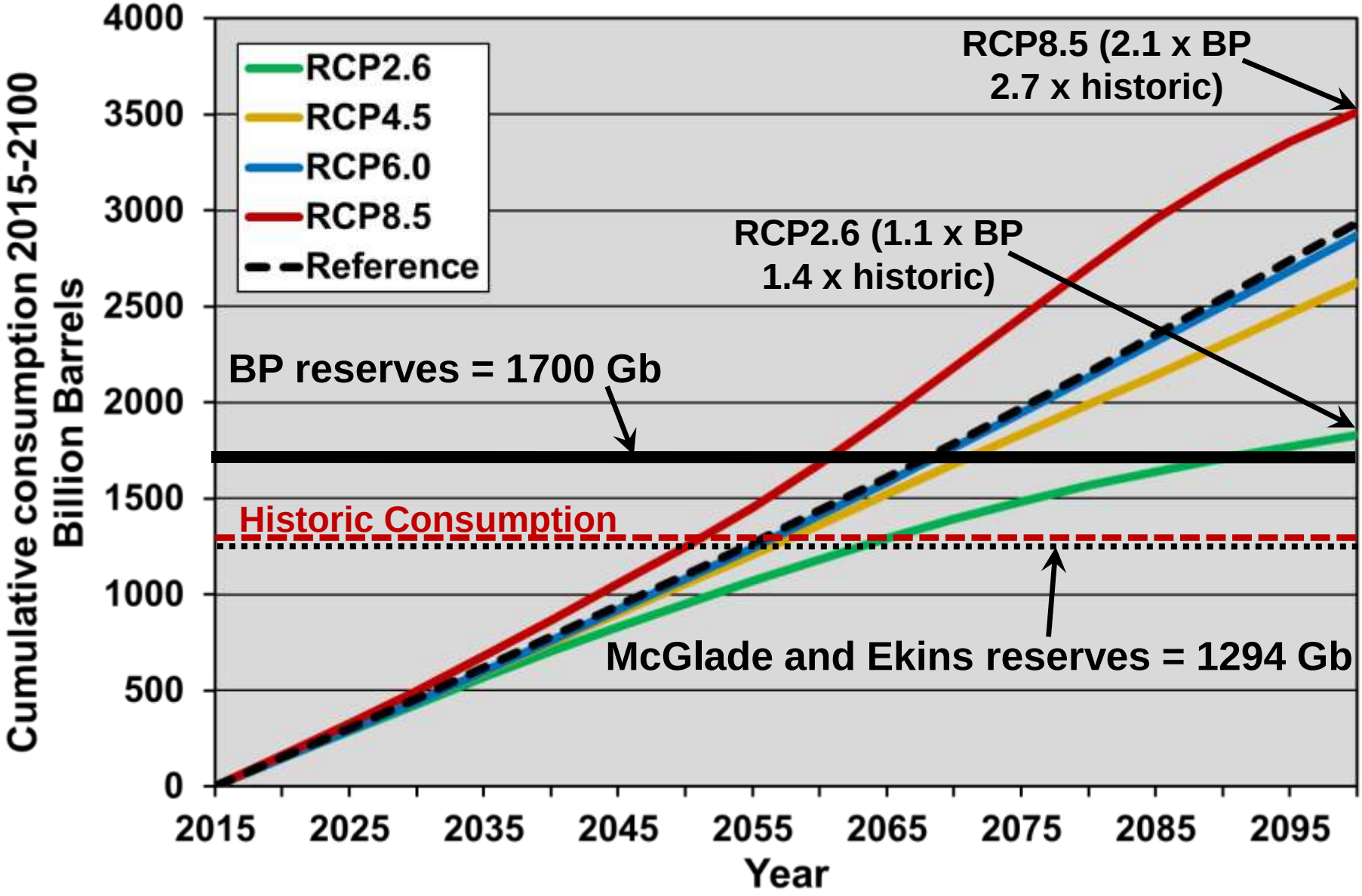


(Arnulf Grubler 1998, BP 2018, NOAA Earth System Research Laboratory and Hadcrut 4 Global annual data retrieved February, 2019)

Peak Fossil Fuels according to Laherrere (2015)

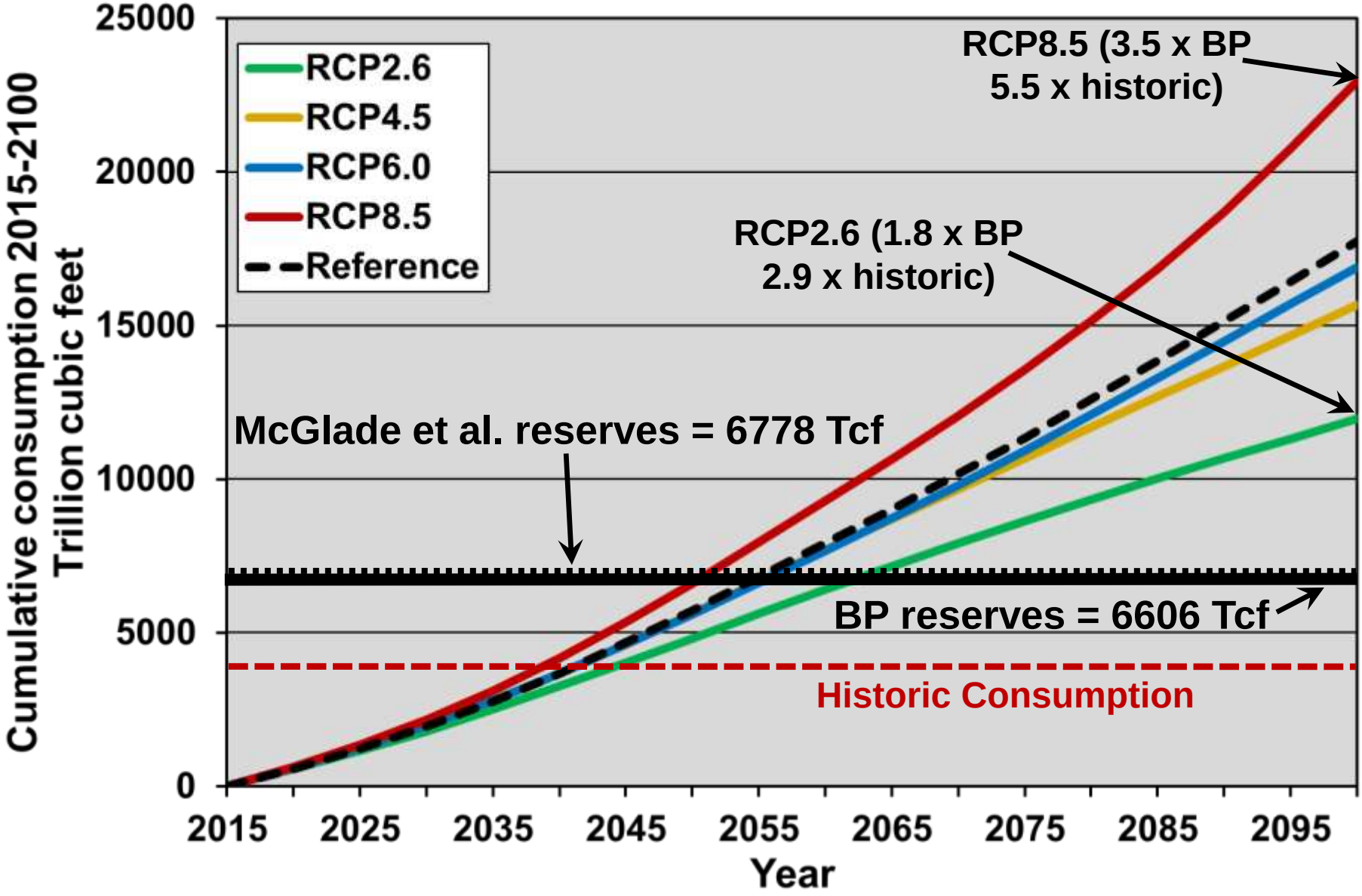


Oil Consumption in IPCC Scenarios Compared to McGlade et al. and BP reserves, 2015-2100



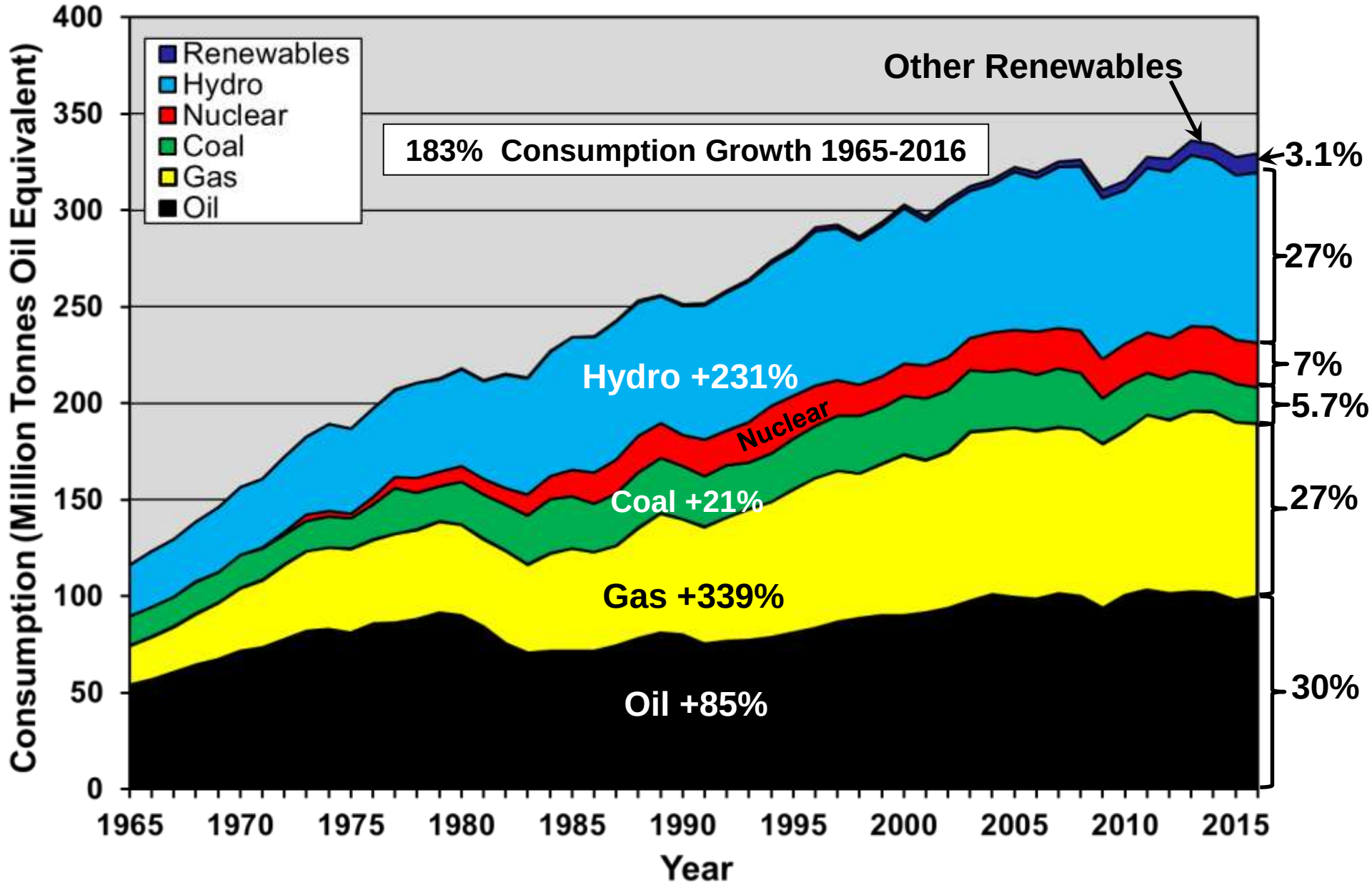
(data from charts in Thomson et al., 2011, Climatic Change 109:77-94; BP, 2015;McGlade et al., 2015)

Gas Consumption in IPCC Scenarios Compared to McGlade et al. and BP reserves, 2015-2100



(data from charts in Thomson et al., 2011, Climatic Change 109:77-94; BP, 2015;McGlade et al., 2015)

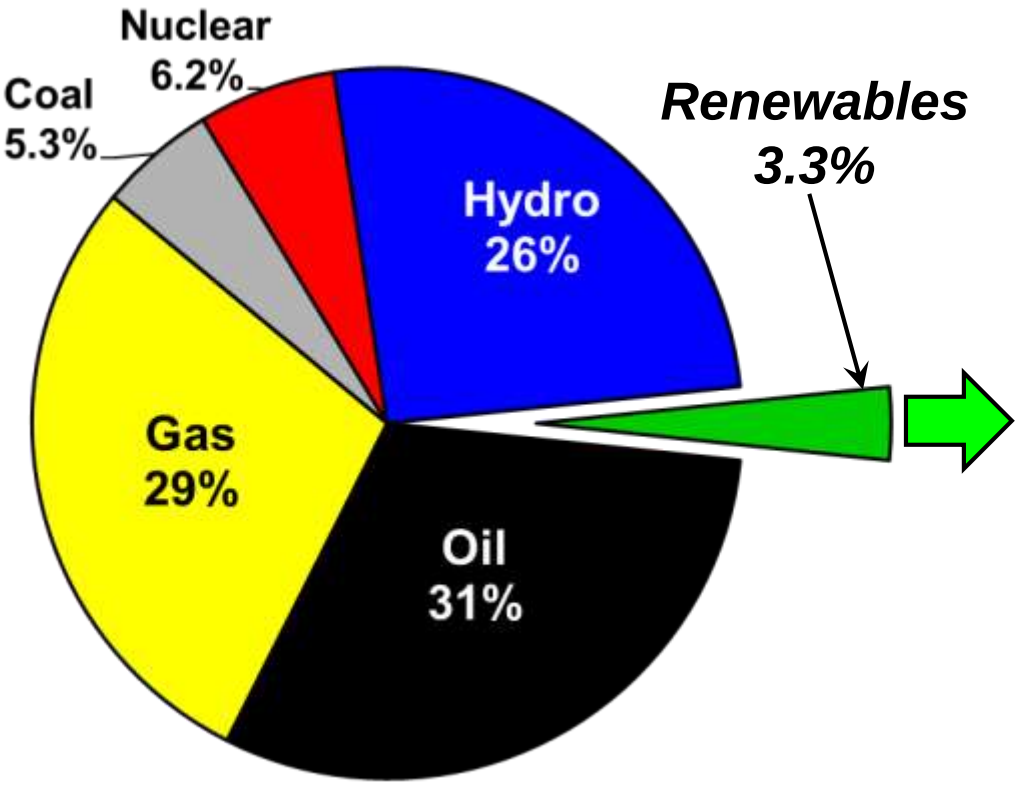
Canada Energy Consumption by Fuel, 1965-2016



(BP Statistical Review, 2017; other renewables include wind, solar, biomass, geothermal and biofuels)

Canada Primary Energy Consumption by Source in 2017
A Comparison to Total Non-Hydro Renewable Energy

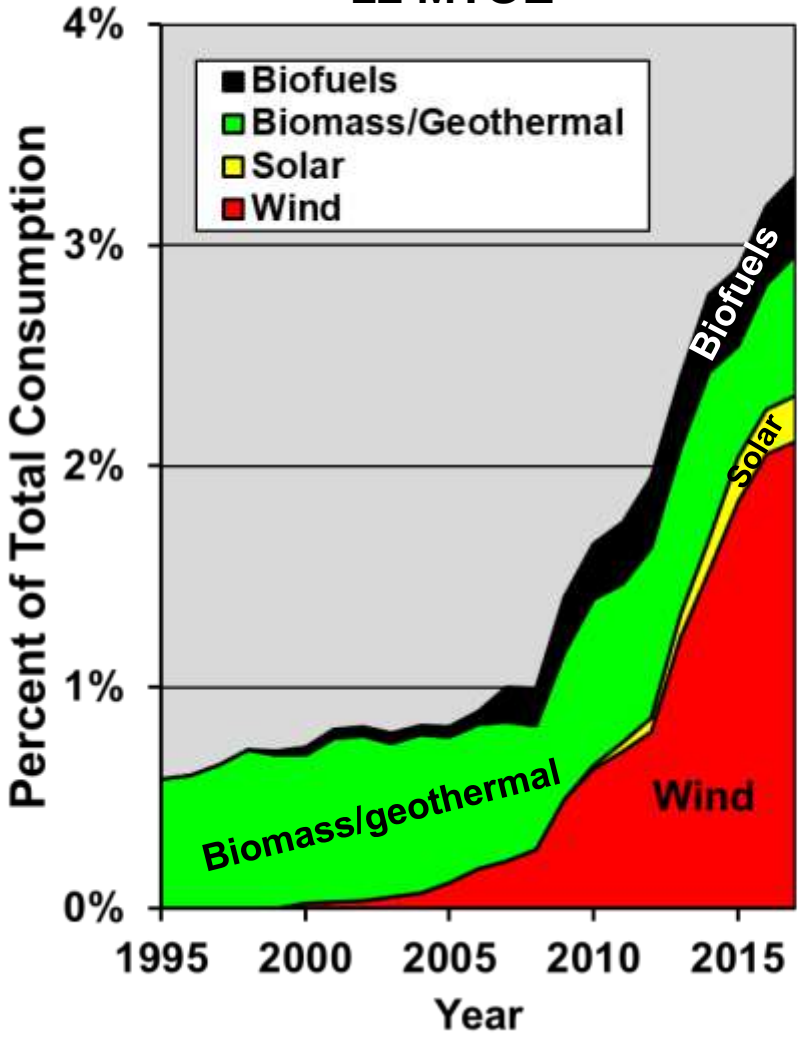
Total Energy by Source
349 MTOE



Large Hydro plus Renewables = 29%

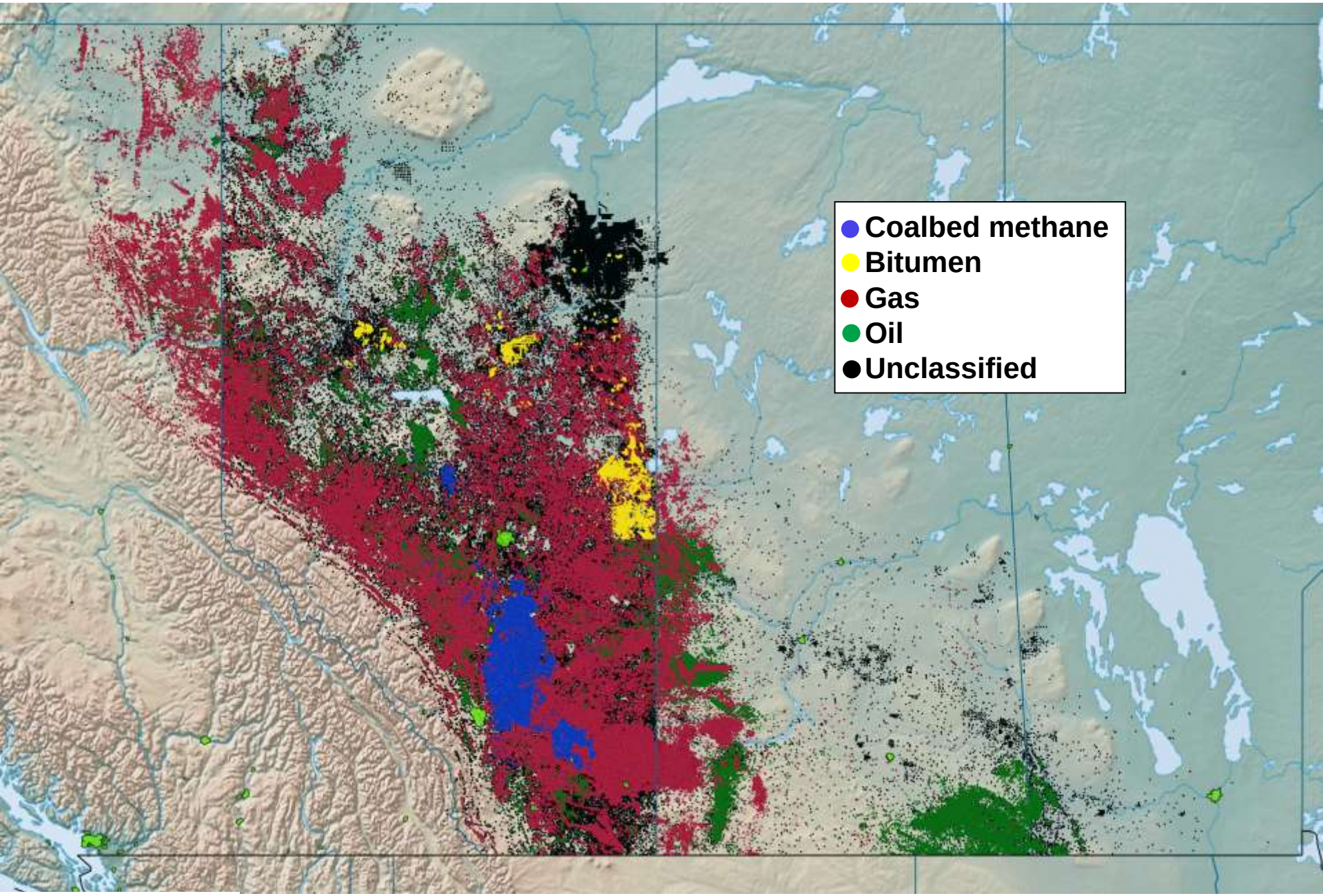
Total consumption has increased by 70% more than all 2017 non-hydro renewables since 2010

Renewable Energy by Source
12 MTOE



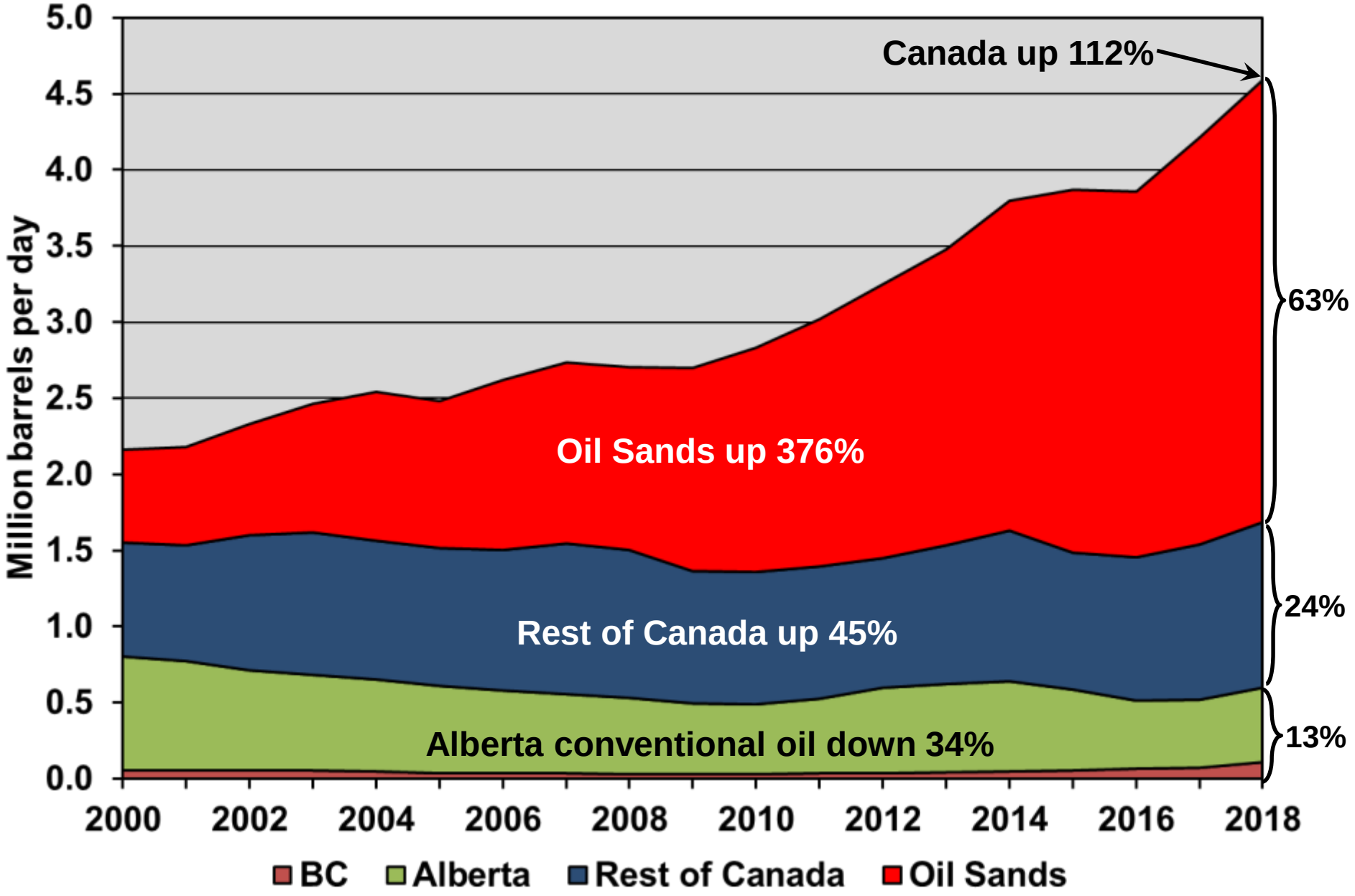
(data from BP Statistical Review of World Energy, 2018)

Oil and Gas Wells in Canada by Type



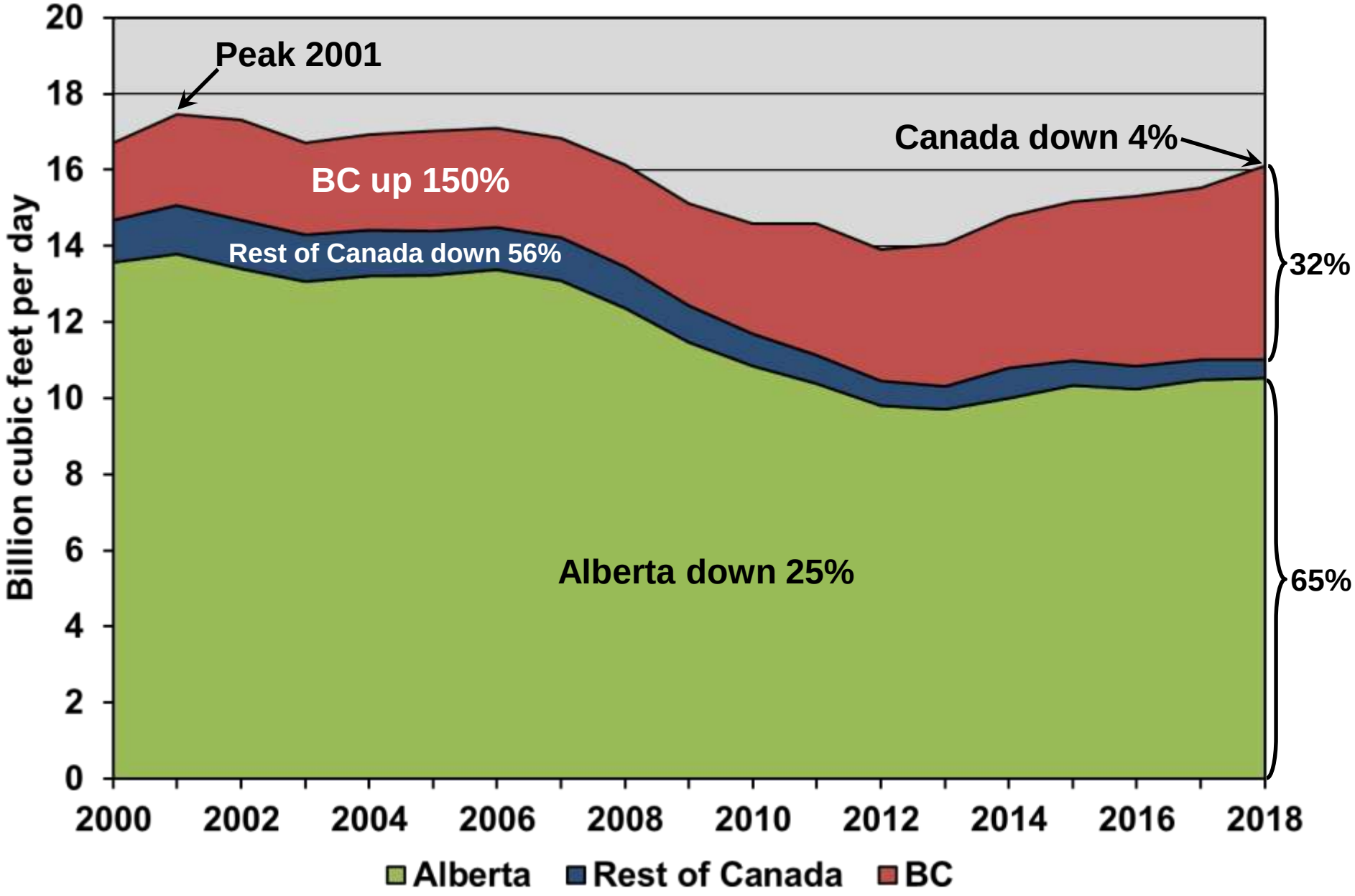
(data from Drillinginfo, December, 2015)

Canada Oil Production, 2000-2018



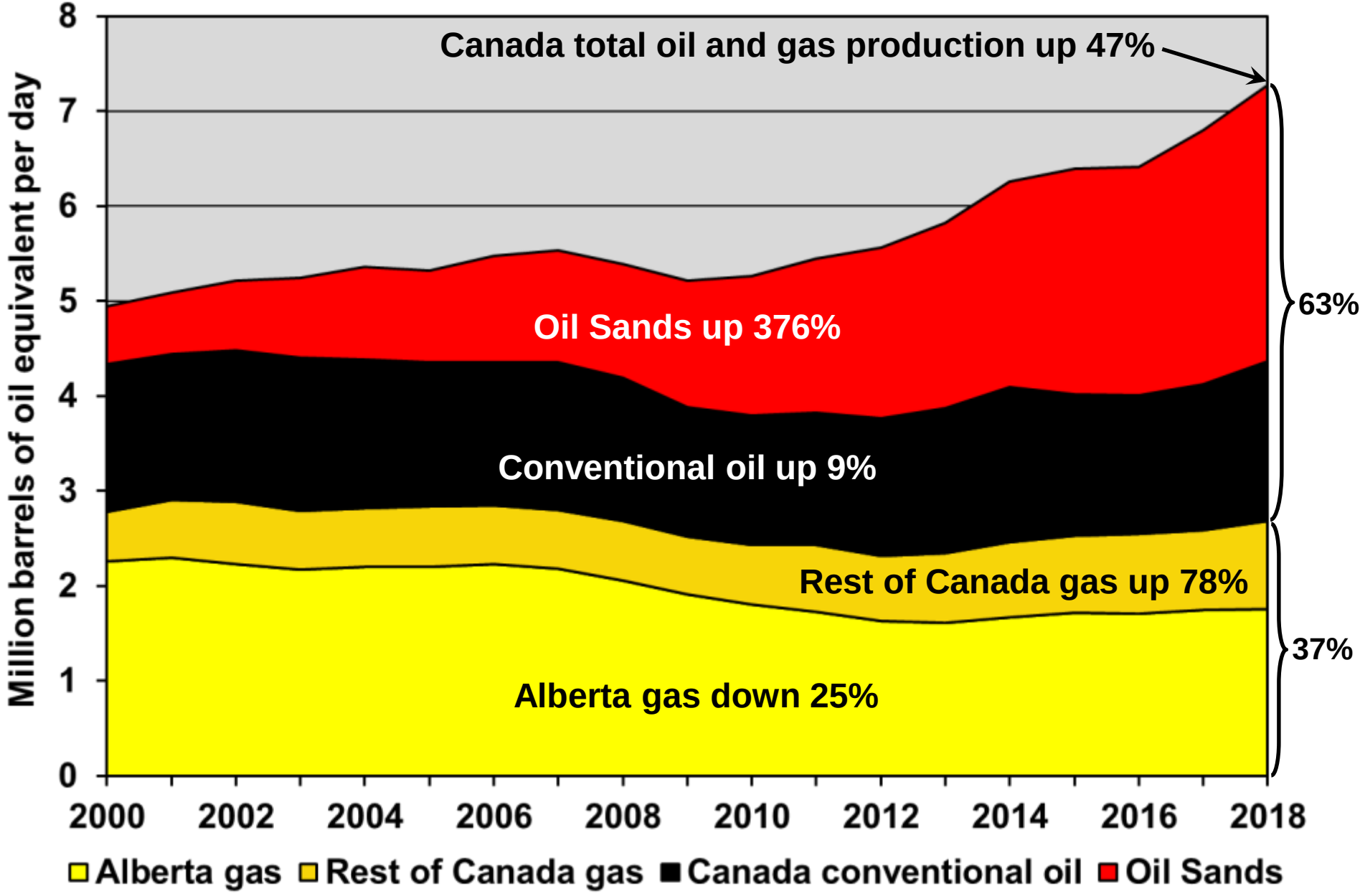
(National Energy Board February, 2019)

Canada Natural Gas Production, 2000-2018



(National Energy Board February, 2019)

Canada Oil and Gas Production, 2000-2018



(National Energy Board February, 2019)

Narrative:

- Growing oil and gas production is essential otherwise there will be no money for roads, schools and hospitals.

Fact:

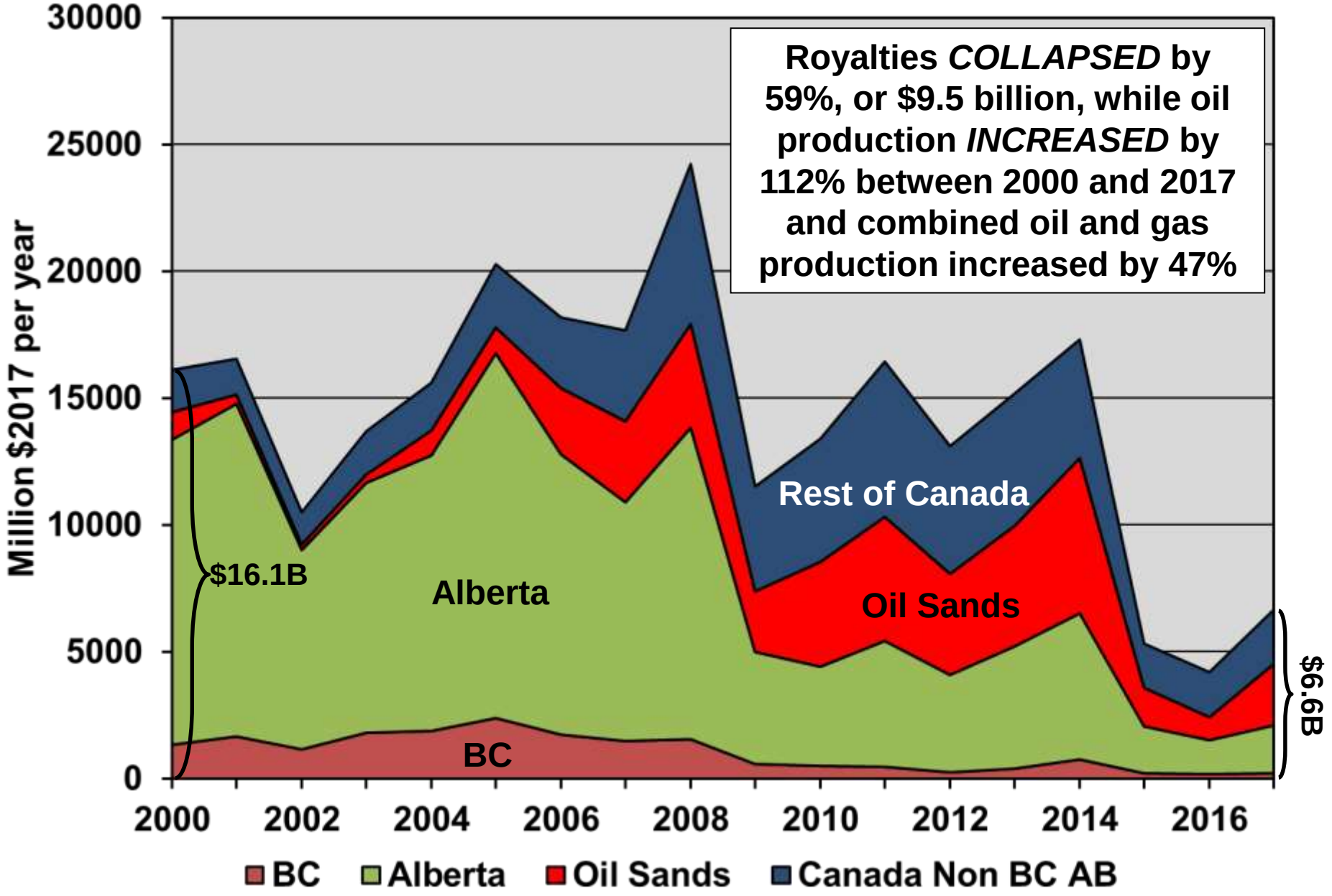
- Royalties have collapsed by 59% or $9.5 billion from 2000 to 2017 despite more than doubling oil production and increasing combined oil and gas production by 47%.

- Royalty percentage on sales revenue in Canada has collapsed from 18.3% to 6.2% from 2000 to 2017 and from 19.5% to 5.1% in Alberta. BC royalties dropped from 19.4% to 3.7% over the same period.

- Returns on expenditures for the oil and gas industry have been marginal over the past 10 years.

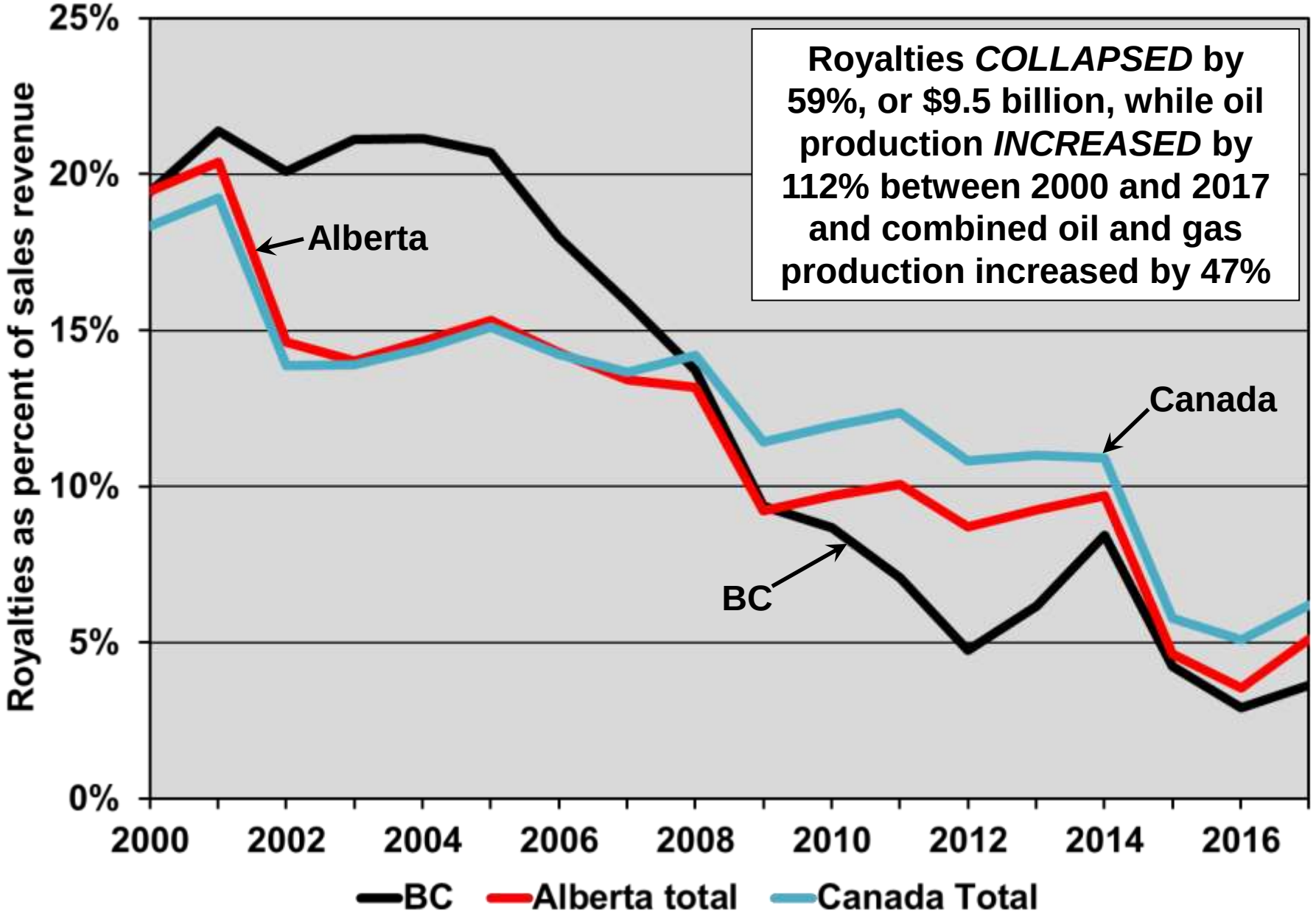
(Canadian Association of Oil Producers Statistical Handbook February, 2019)

Canada Oil and Gas Royalty Payments, 2000-2017



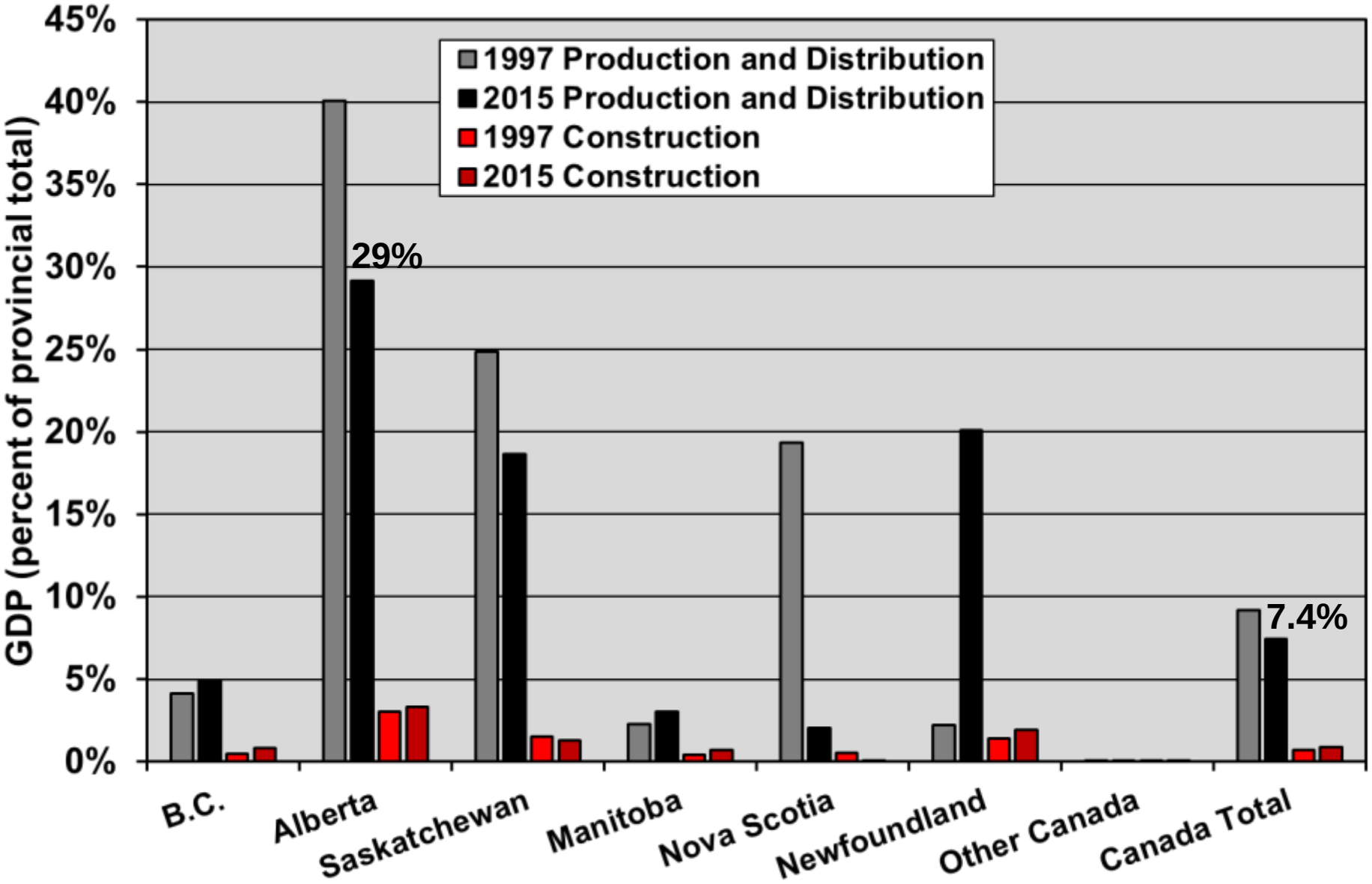
(Canadian Association of Oil Producers Statistical Handbook February, 2019)

Royalties as Percentage of Sales Revenue, 2000-2017



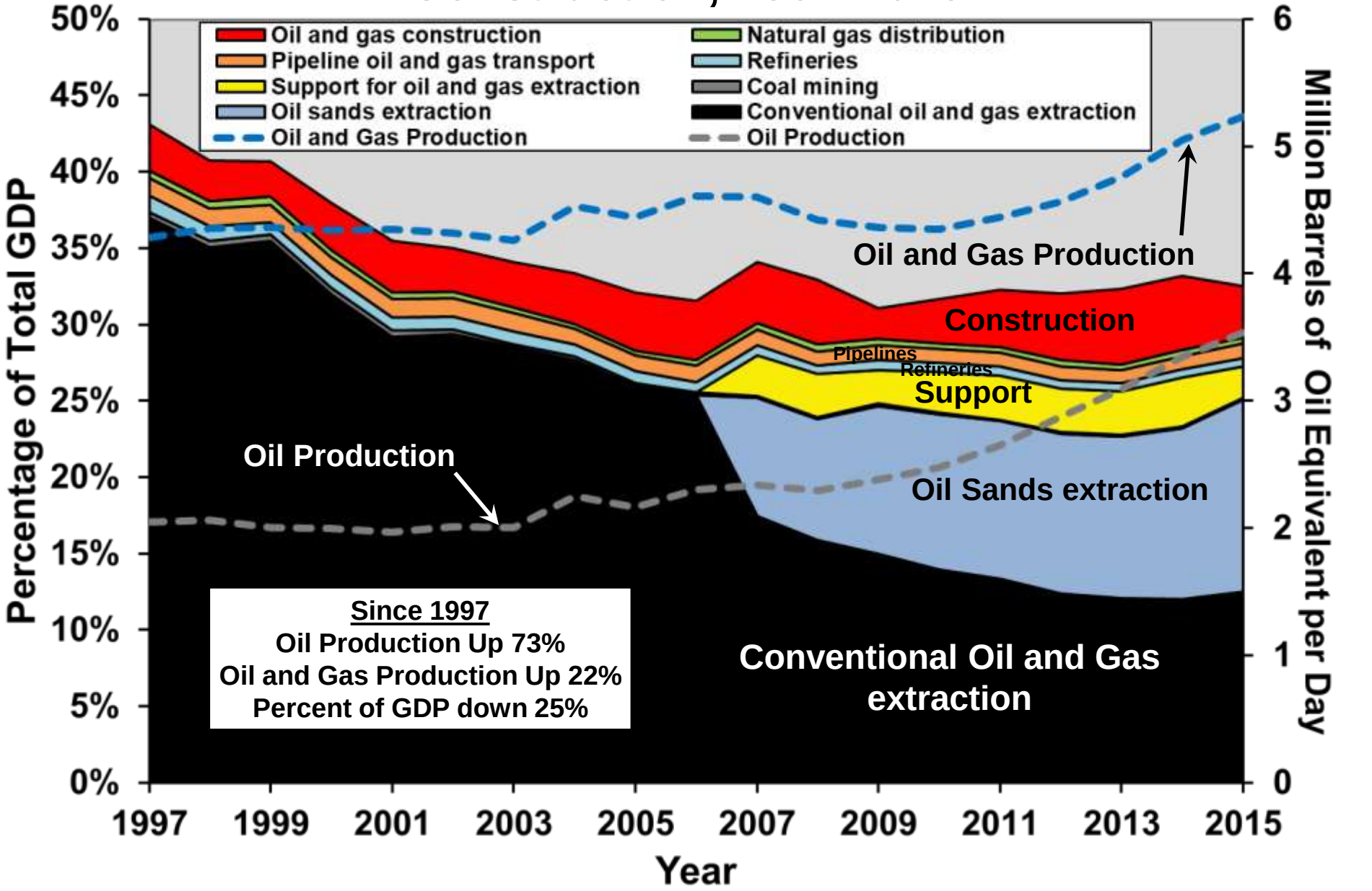
(Canadian Association of Oil Producers Statistical Handbook February, 2019)

GDP from Fossil Fuel Production, Distribution and Construction as Percent of Provincial GDP,1997 and 2015



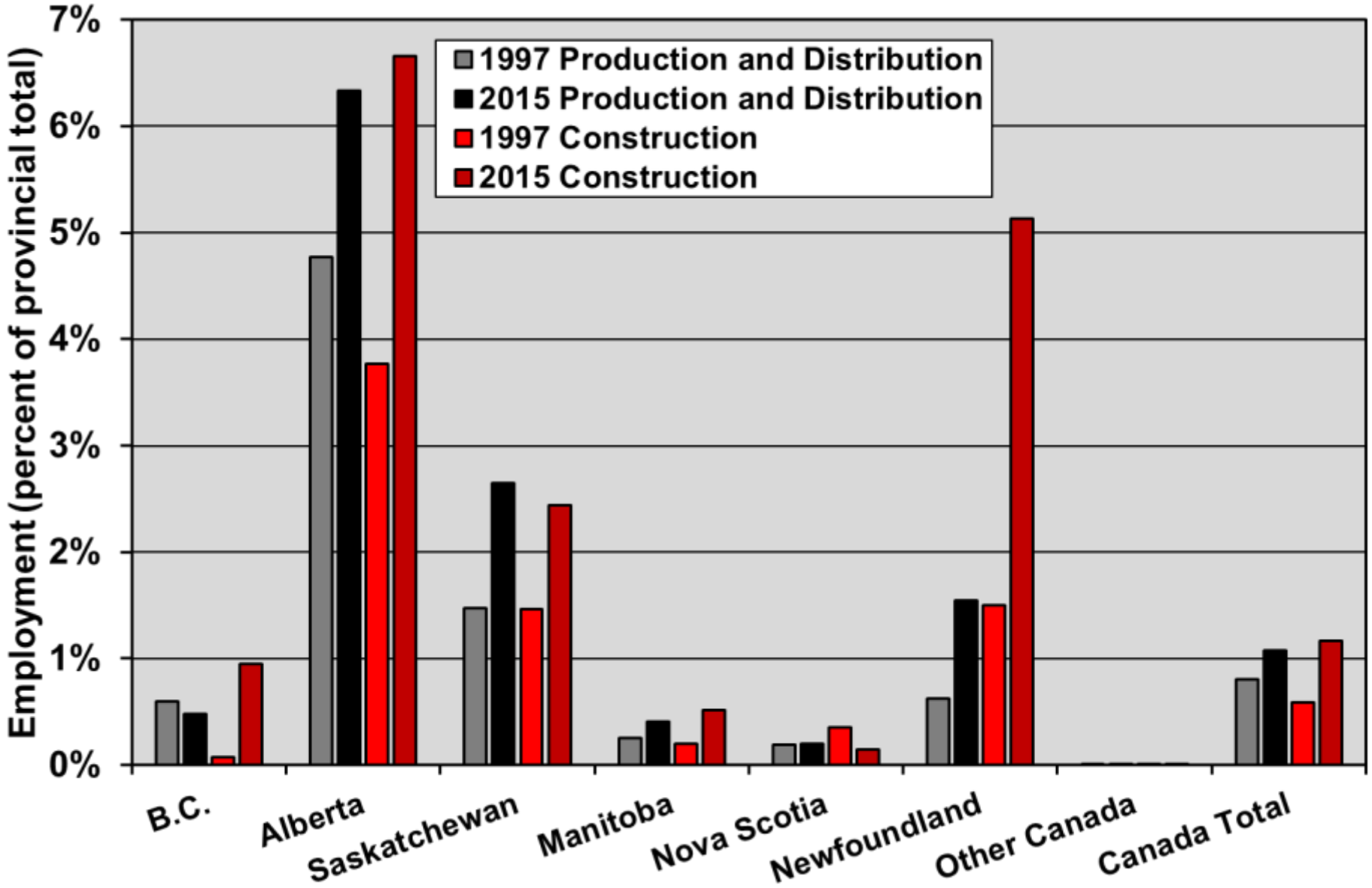
(data from Statscan Table 379-0030)

Alberta GDP from Fossil Fuel Production, Distribution and Construction, 1997-2015



(data from Statscan Table 379-0030)

Percent of total Employment by Province in Fossil Fuel Production, Distribution and Construction,1997-2015



(data from Statscan Table 383-0031)

Narrative:

- Canadian oil has less emissions and is 'ethical' hence we need pipelines to the east to stop importing Saudi Arabia and other 'unethical' crude.

Fact:

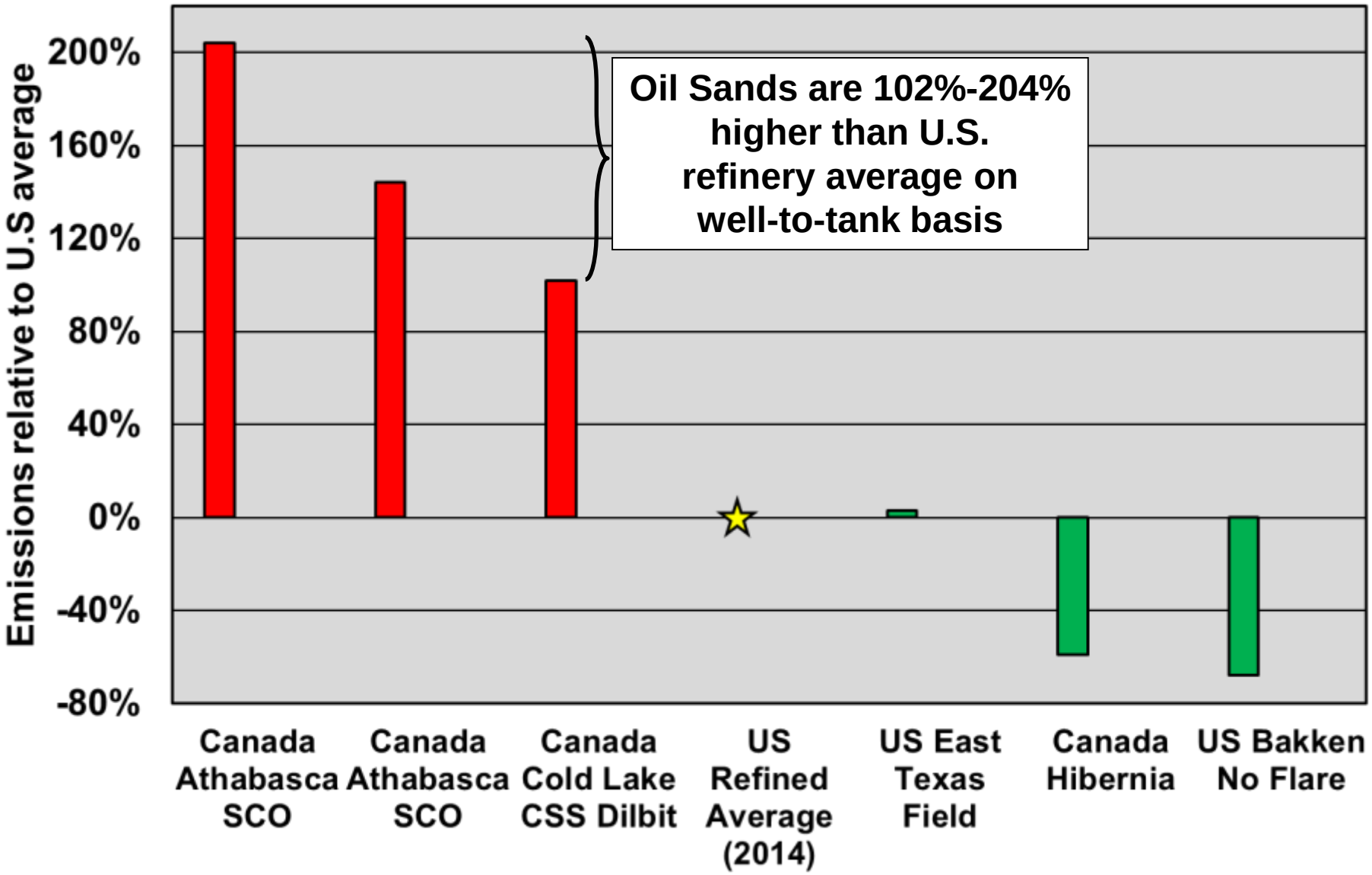
- On a well-to-tank basis, oil sands are 102% to 204% higher than the US refinery average. On a well-to-wheels basis they are up to 24% higher.

- Saudi Arabia imports are less than 8% of Canadian consumption, whereas US imports are about 25%.

- Eastern refineries in New Brunswick are not optimized for heavy oil hence an Energy East pipeline would not stop imports and would mostly be destined for exports at compromised prices due to higher transport costs.

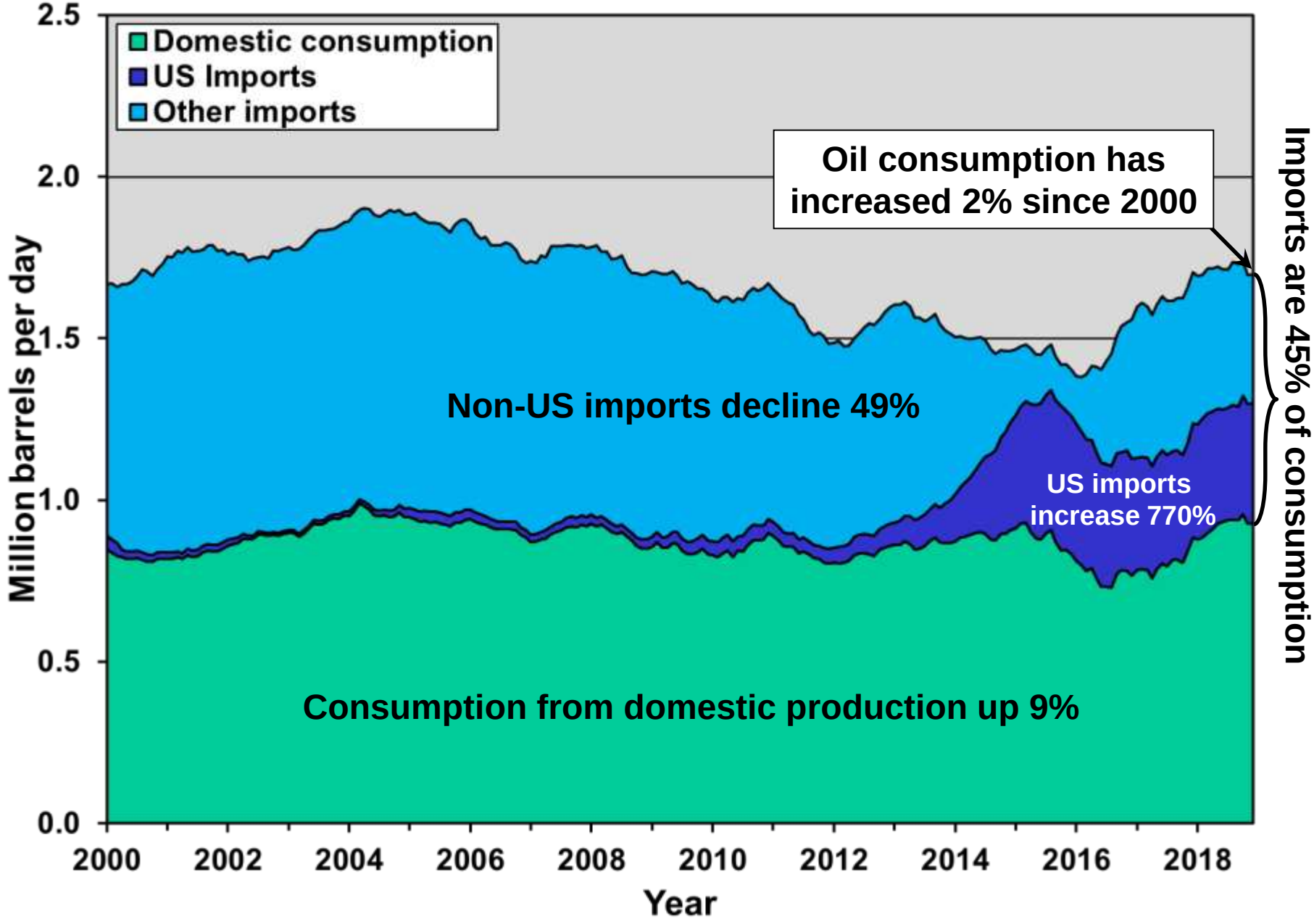
(ARC Energy Research Institute 2017; Canadian Association of Oil Producers Statistical Handbook February, 2019)

Well-to-Tank Emissions of Oil Sands compared to U.S. Refined Average



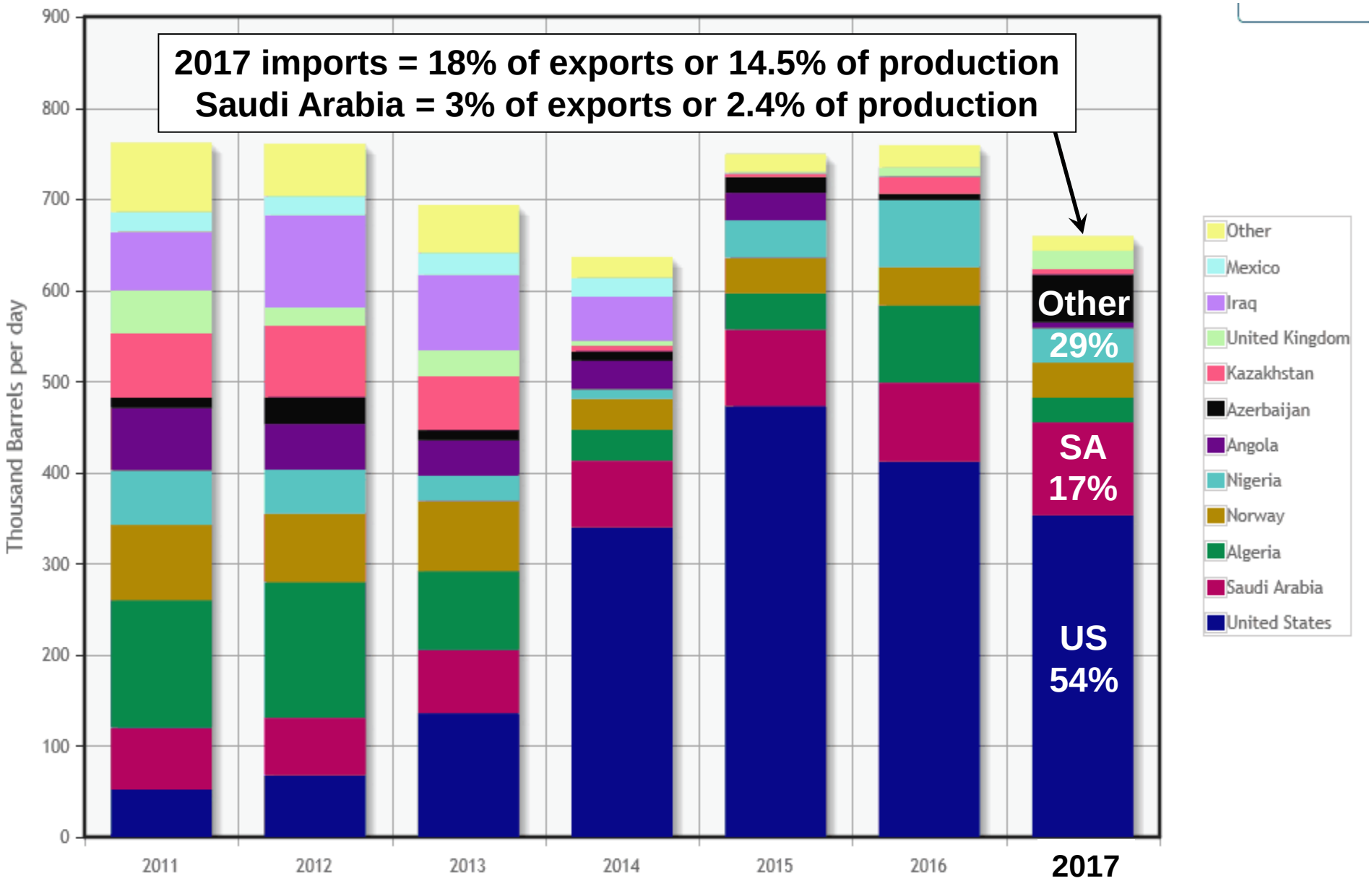
(ARC Energy Research Institute: Crude Oil Investing in a Carbon Constrained World 2017 Update October, 2017)

Canadian oil consumption and imports, 2000-2018



(Data from Statscan Table 25-10-0063-01 retrieved February, 2018; 12 month trailing average)

Canadian Crude Oil Imports by Country of Origin



(Figure from National Energy Board, March 2018)

Narrative:

- "We have been the victims of a very well-orchestrated, well-planned foreign-funded attack on Canadian infrastructure" (CAPP February 27, 2019).

Fact:

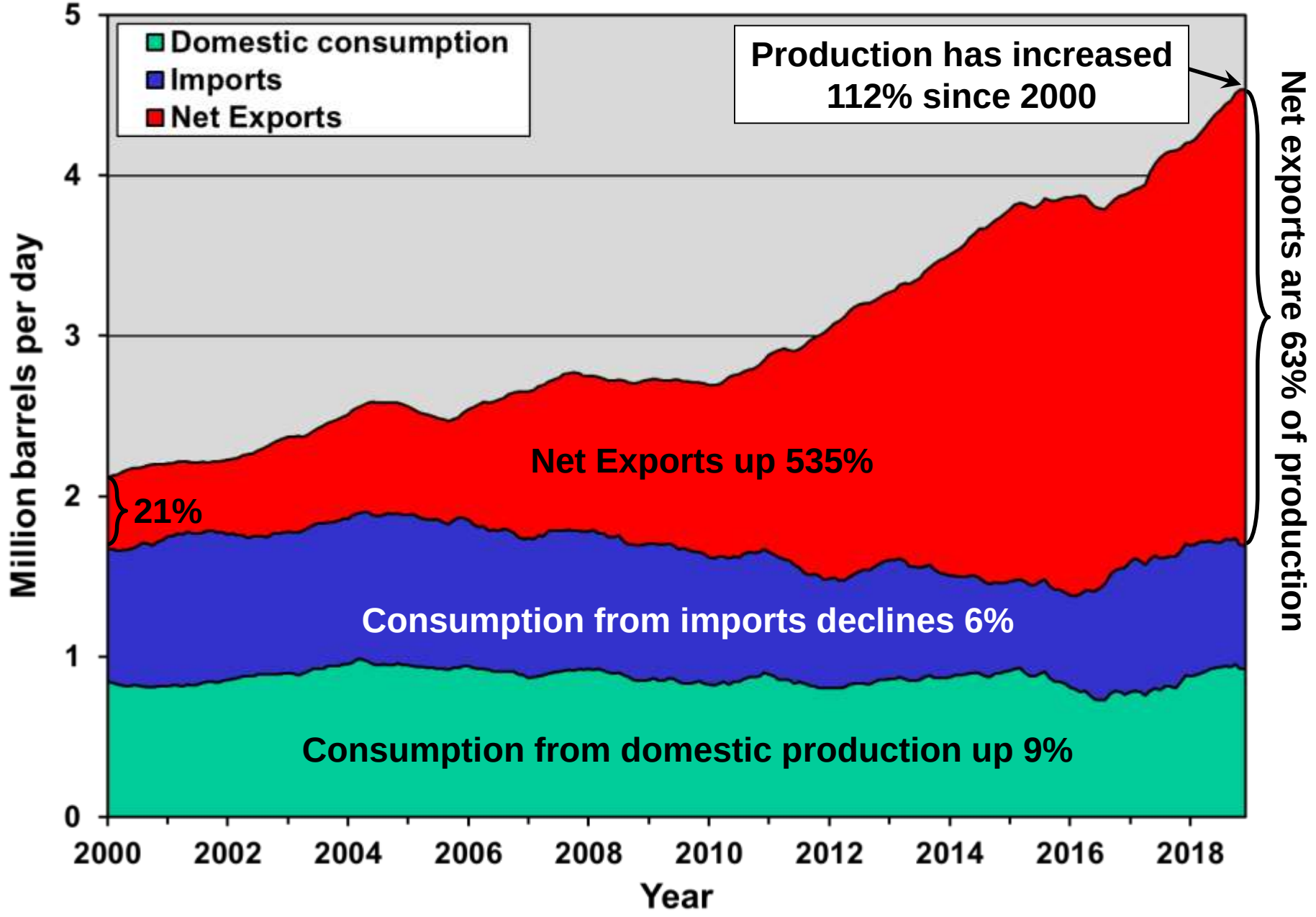
- The reason that there is a pipeline bottleneck is that the industry has been so successful in growing production.

- Oil sands production is up 376% since 2000 and overall oil and gas production is up 47%. This alleged 'foreign-funded attack' has been very ineffective.

- CAPP's idea of a coherent energy plan is to double industry's growth rate by 2020 and build four new export pipelines after Line 3 and Keystone XL are completed (CAPP January 22, 2019).

(Alberta Government website, February 2019)

Canadian oil consumption, imports and net exports, 2000-2018



(Data from Statscan Table 25-10-0063-01 retrieved February, 2018; 12 month trailing average)

A Word on Pipelines

Narrative:

- Canada is losing $80 million per day since the August 30, 2018, suspension of the Trans Mountain expansion (TMX) project by the court.

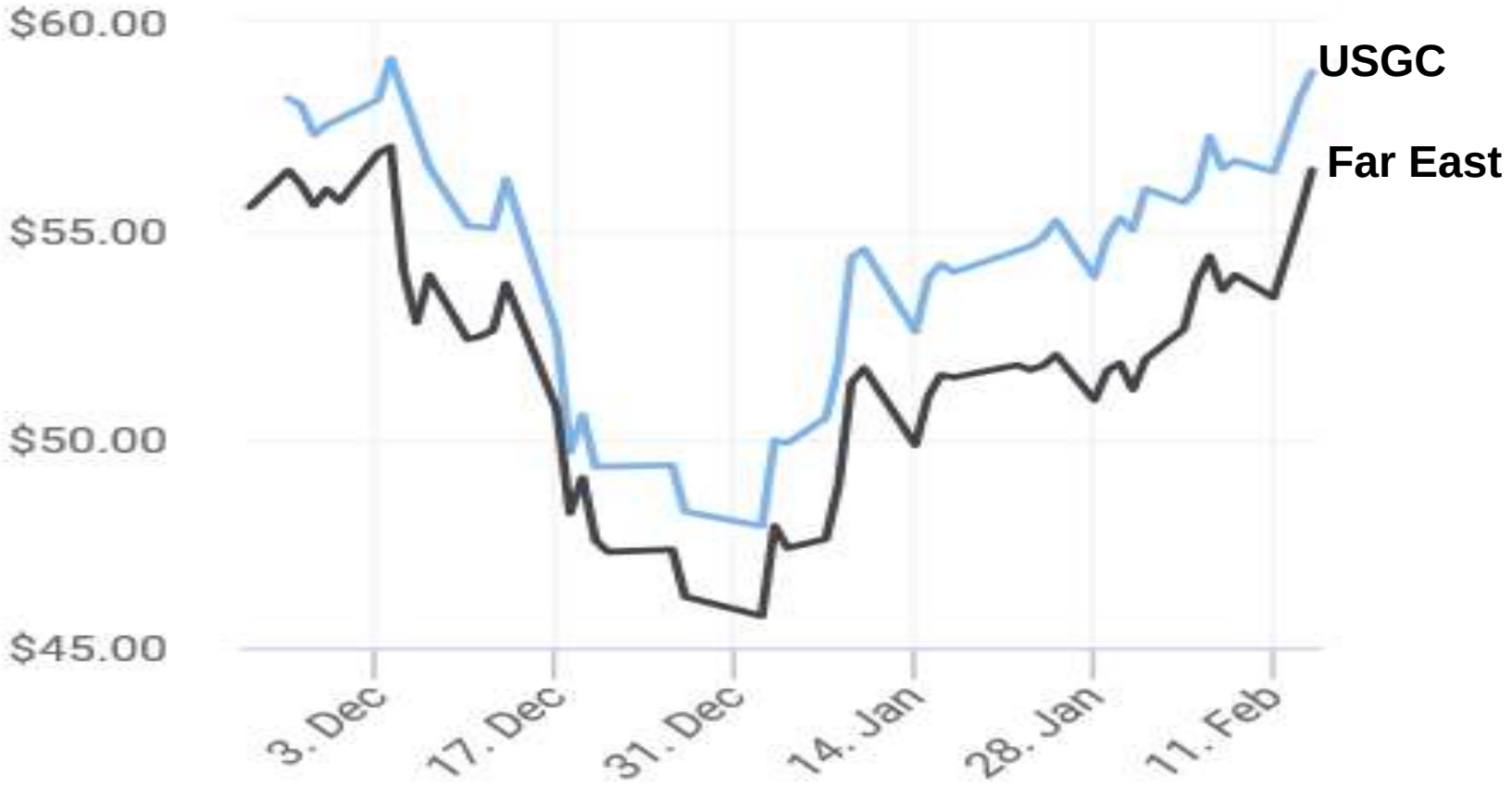
Fact:

- Canada is losing nothing as two new pipelines – Line 3 and Keystone XL - will clear the bottleneck well before TMX could be built in 2022. The current differential of $13 per barrel marks a premium compared to the normal $15 per barrel due to transport costs and quality.

- Oil shipped on TMX to Asia would lose $5 per barrel compared to pipelines under development, due to higher premiums paid on the US Gulf Coast and higher shipping costs to Asia.

(Alberta Government website, February 2019)

Heavy sour crude oil prices on U.S. Gulf Coast versus the Far East, December 2018 to February 2019



(Oilprice.com February 18 2019)

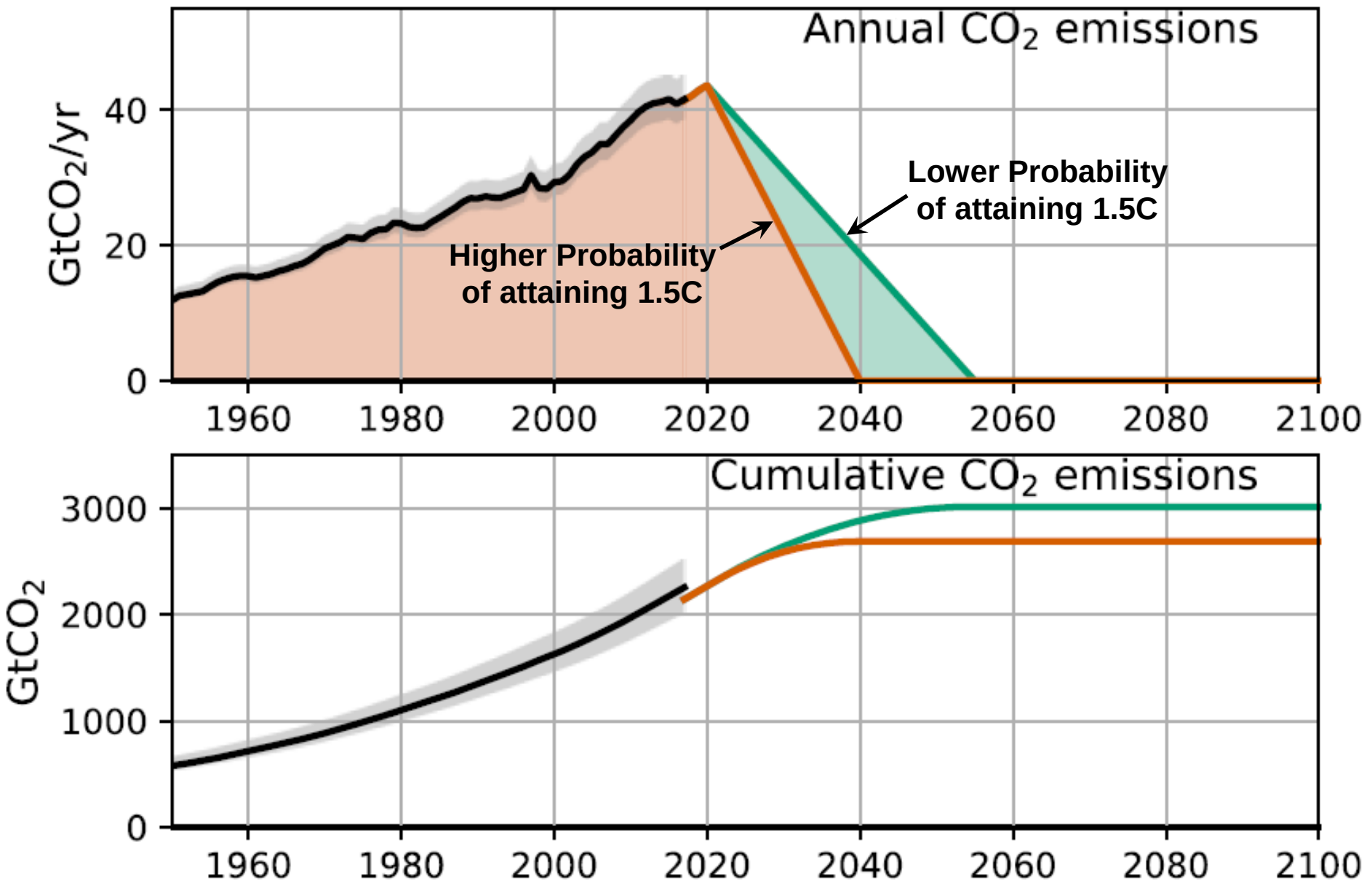
IPCC Special Report on Global Warming of 1.5ºC October 2018

"Limiting global warming to 1.5ºC would require rapid, far-reaching and unprecedented changes in all aspects of society."

"Global net human-caused emissions of carbon dioxide (CO2) would need to fall by about 45 percent from 2010 levels by 2030, reaching 'net zero' around 2050. This means that any remaining emissions would need to be balanced by removing CO2 from the air."

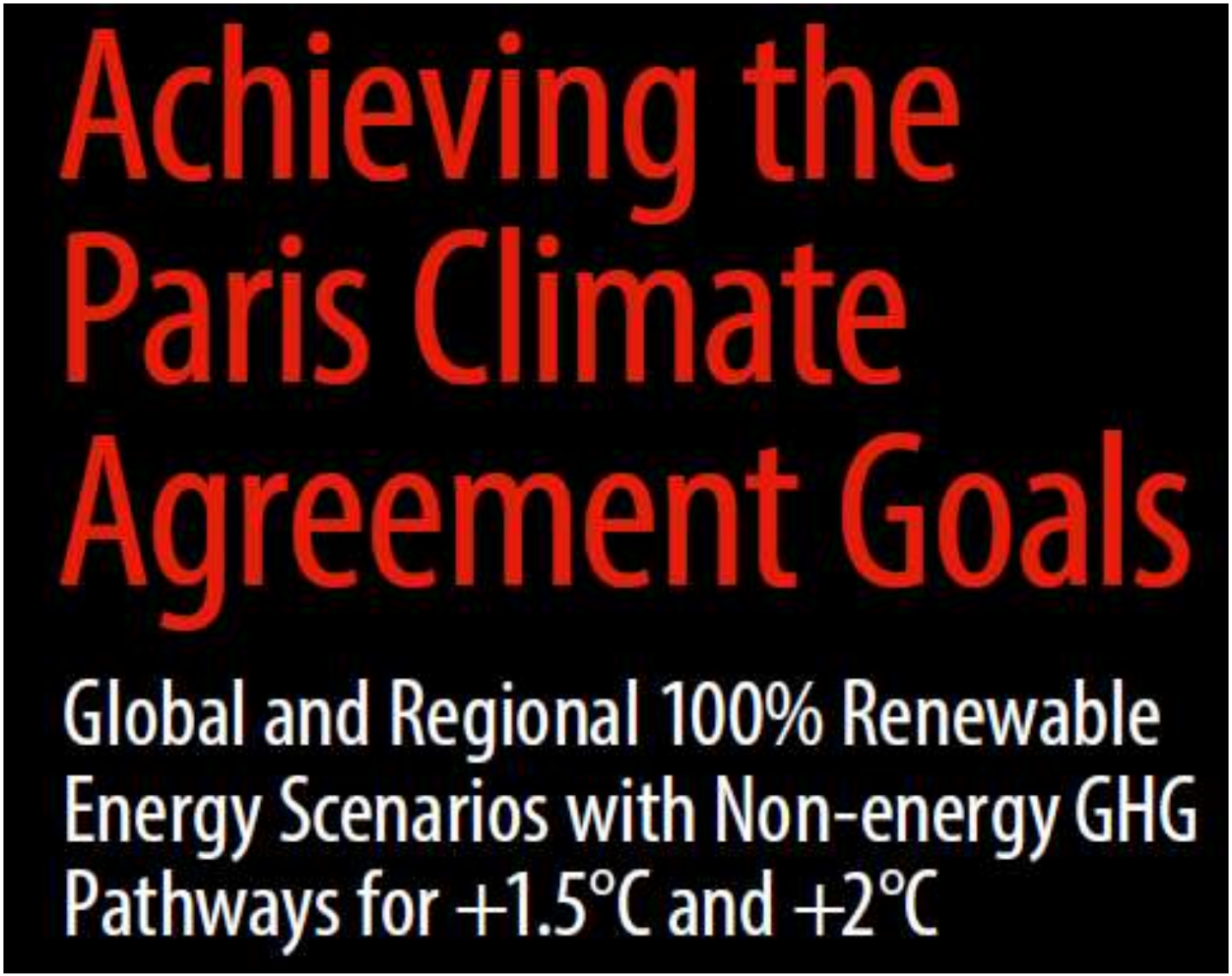
(IPCC Press release, October 2018)

IPCC Special Report on Global Warming of 1.5ºC



(IPCC Chapter 1 annex, October 2018)

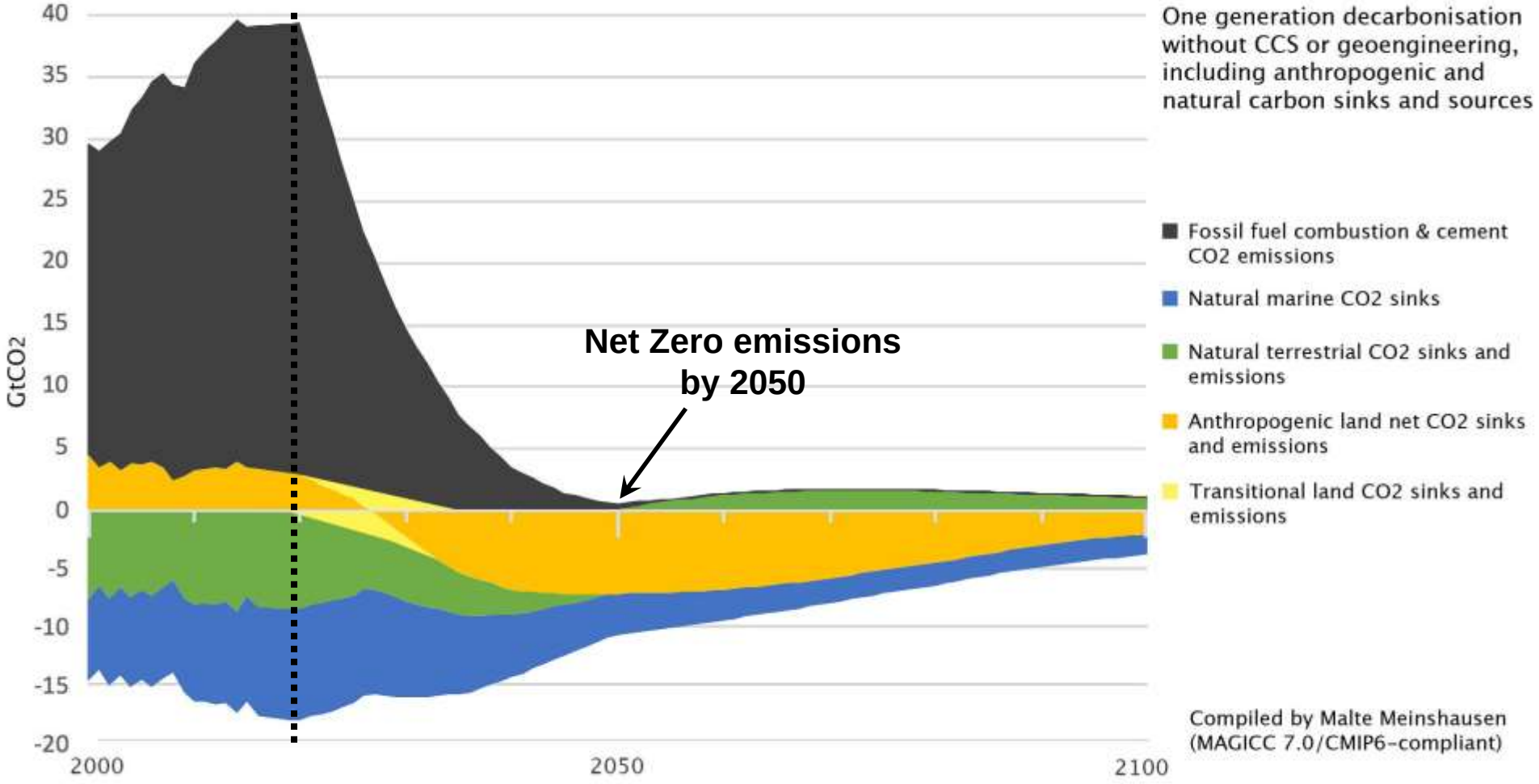
DiCaprio Foundation, February 2019



Free download from Springer.com

(download link https://link.springer.com/content/pdf/10.1007%2F978-3-030-05843-2.pdf)

DiCaprio Foundation, February 2019



(from https://www.leonardodicaprio.org/one-earth-climate-model/)

How is Canada doing so far?

Pan-Canadian Framework:

- ***Emissions reduction target of 30% below 2005 levels by 2030.***
- ***'Current policies' will reduce emissions by only 4% without counting currently disallowed Land Use, Land Use Change and Forestry (LULUCF) which would decrease emissions by 9%.***
- ***With 'Additional measures' reductions would be 14% without disallowed LULUCF and buying carbon credits and 19% with them.***

Alberta Climate Leadership Plan:

- ***Allows oil sands emissions to grow by 40% over 2016 levels.***
- ***Would see Alberta's emissions increase by 19% over 2005 levels.***

Both of these plans have some good initiatives including carbon taxes and incentives for efficiency

(Projections from ECCC 2018 Canada's greenhouse gas and air pollutant projections, January 2019)

Narrative:

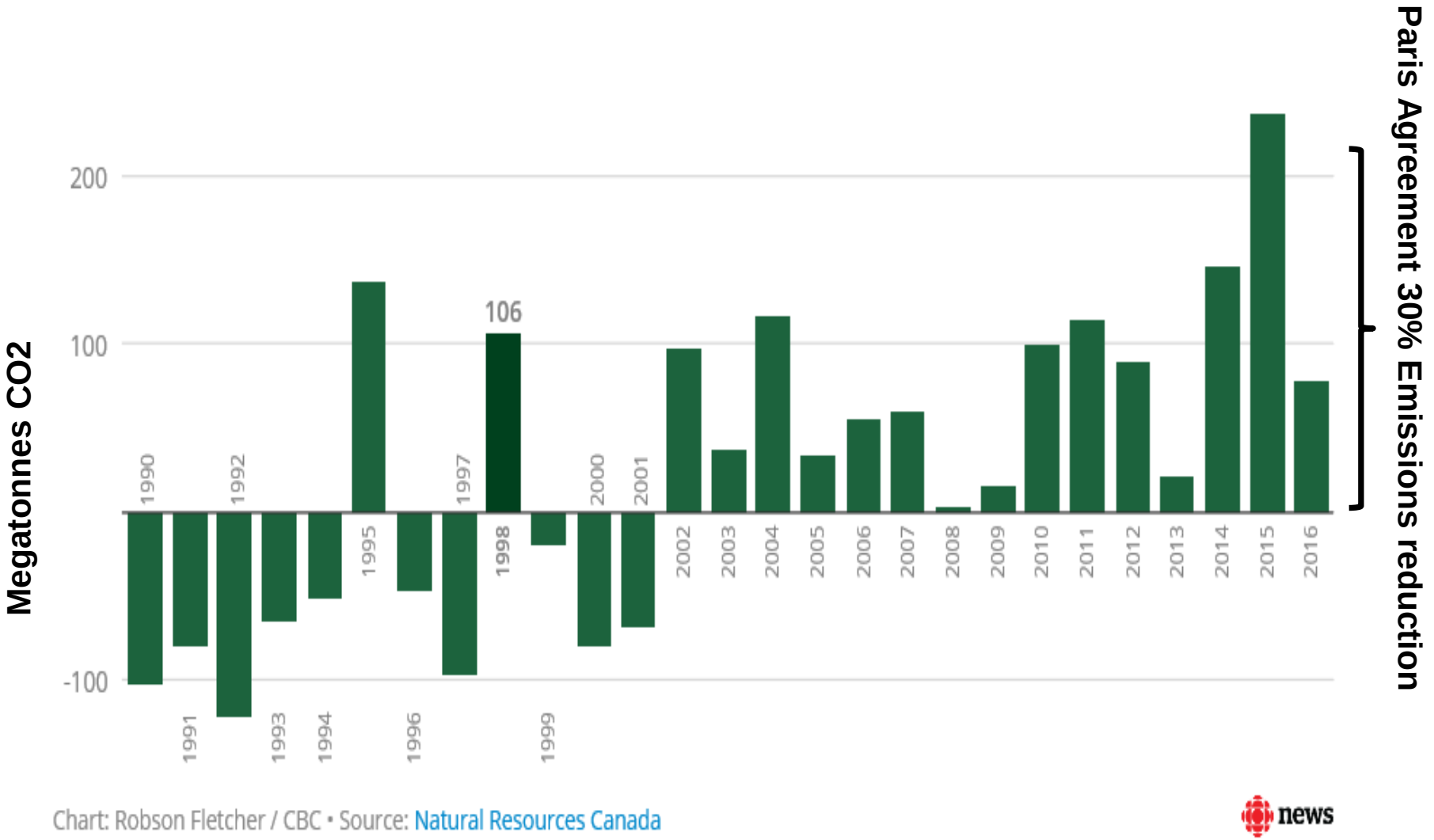
- Canada's vast forests are sequestering more than its share of emissions therefore no worries.

Fact:

- After subtracting the sequestration from tree planting and managed forests, Canada's forests are net emitters of greenhouse gases due to wildfires and insect infestations .

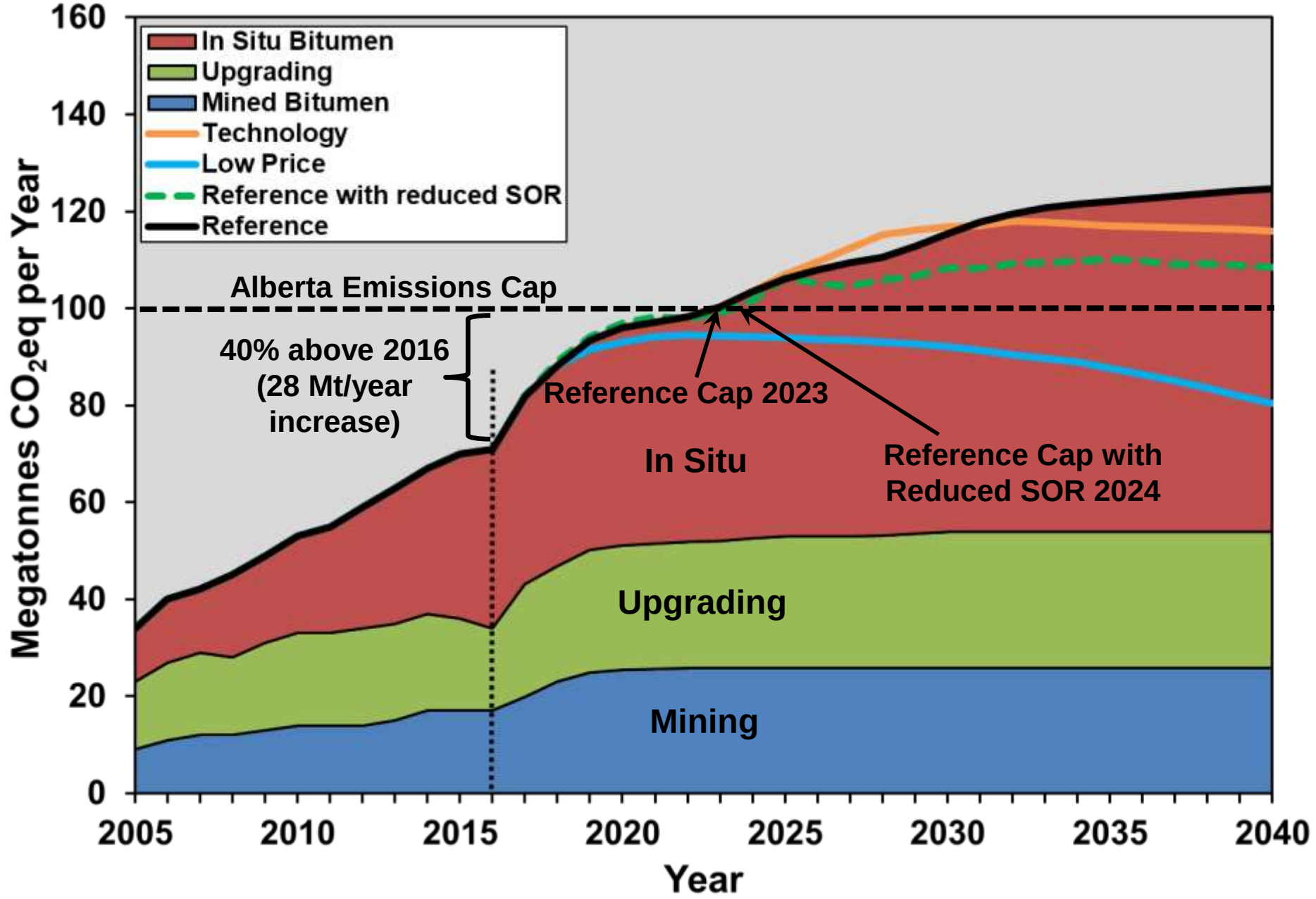
(Alberta Government website, February 2019)

Net Emissions from Canadian Forests due to Wildfires and Insect Infestations, 1990-2016



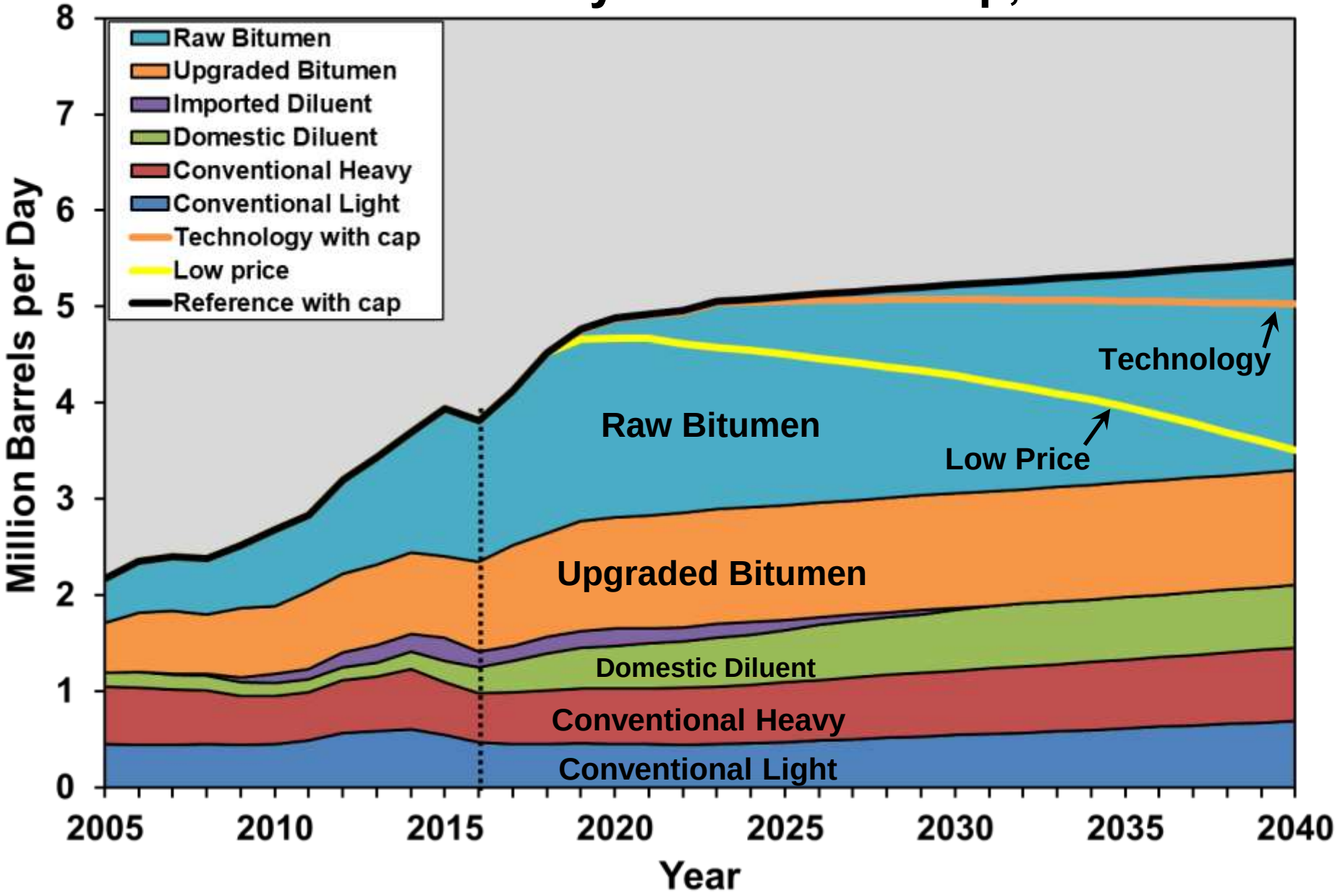
 (From CBC https://www.cbc.ca/news/canada/calgary/canada-forests-carbon-sink-or-source-1.5011490 February 2019)

Oil Sands Emissions in NEB Reference Case, 2005-2040



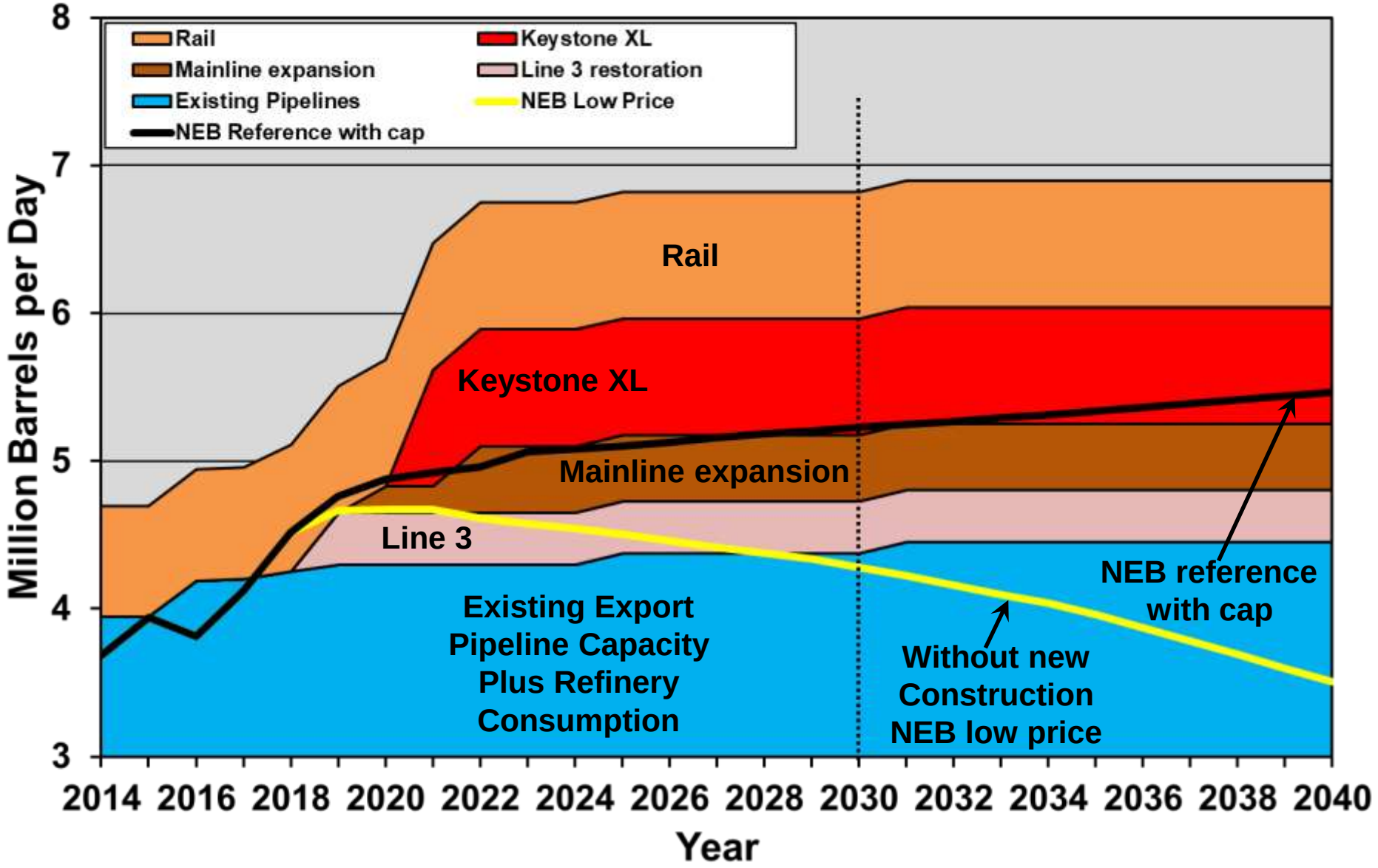
(data from NEB Energy Future 2018, Environment and Climate Change Canada 2018)

Western Canada Supply in NEB Reference Case with with Alberta's 100 Mt/year emission cap, 2005-2040



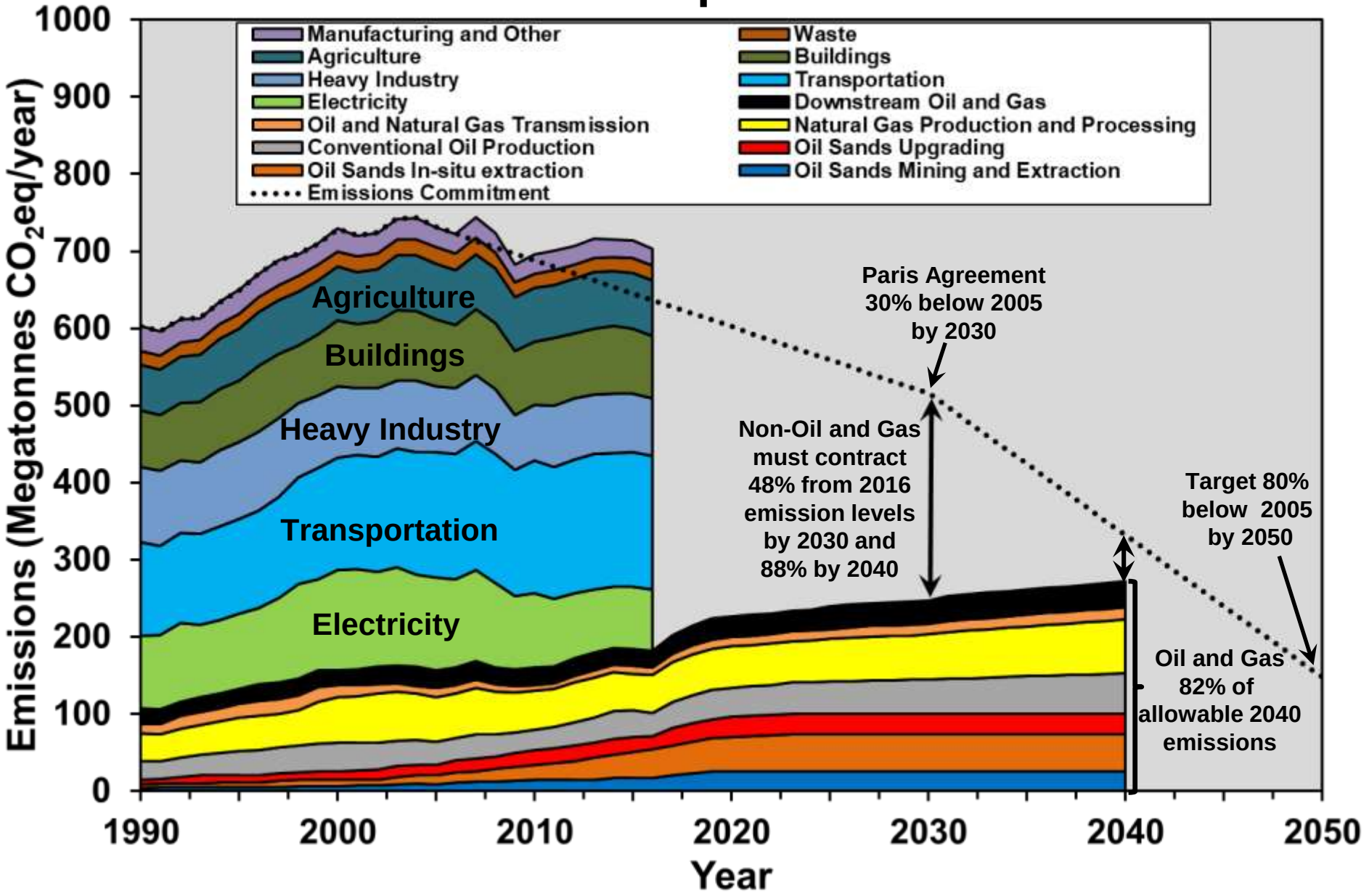
(data from NEB Energy Future 2018; CAPP, 2018)

WCSB Supply compared to refinery demand, existing export pipeline and rail capacity and proposed capacity



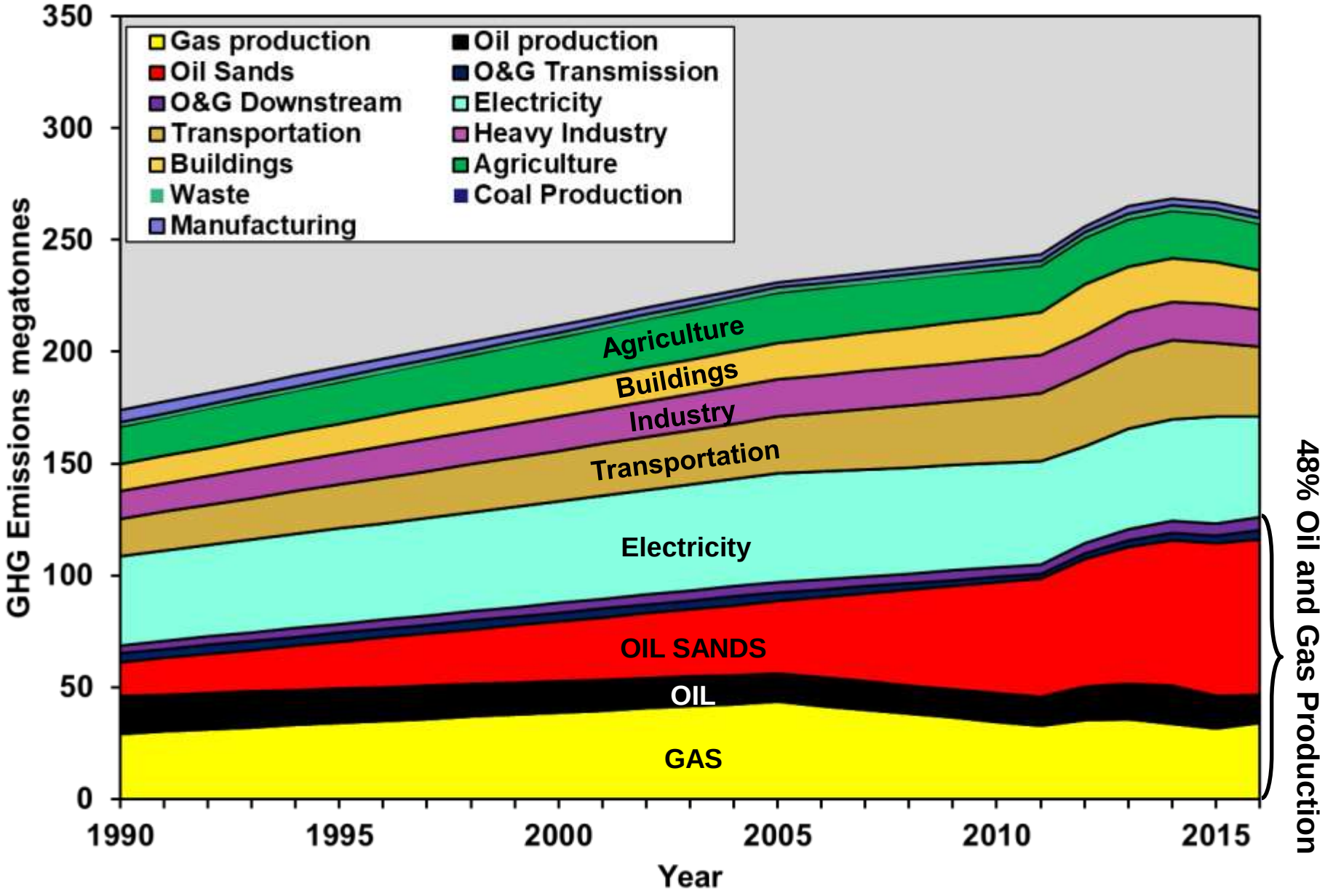
 (data from CAPP Oil Forecast 2018; National Energy Board, Canada's Energy Future 2018 and author calculations)

Emissions by Sector, NEB Reference Case Oil and Gas Forecast with Emissions Cap and Climate Commitment



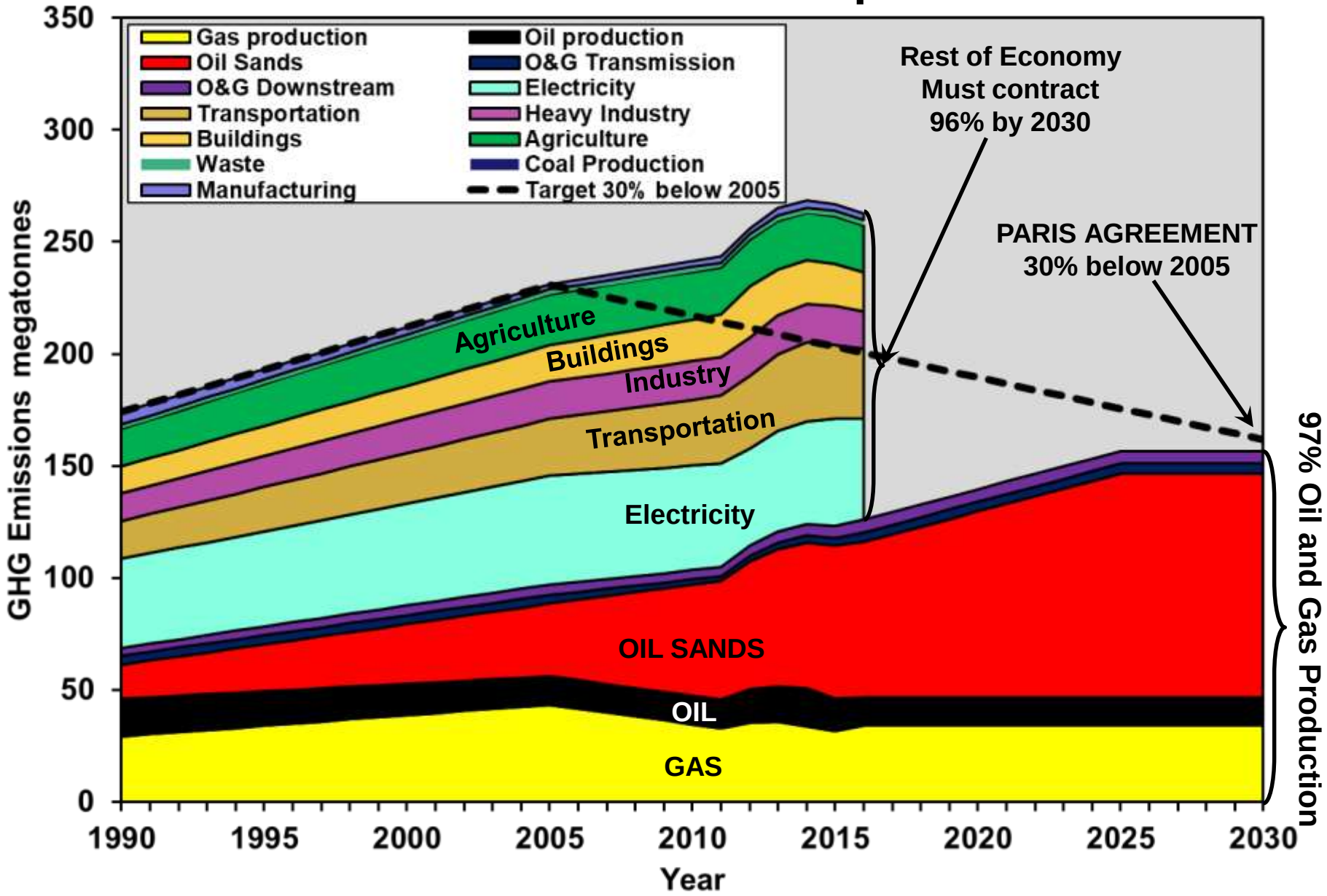
(data from ECCC National Inventory Report 2018; NEB Energy Future 2018; Government climate commitments)

GHG Emissions in Alberta 1990-2016



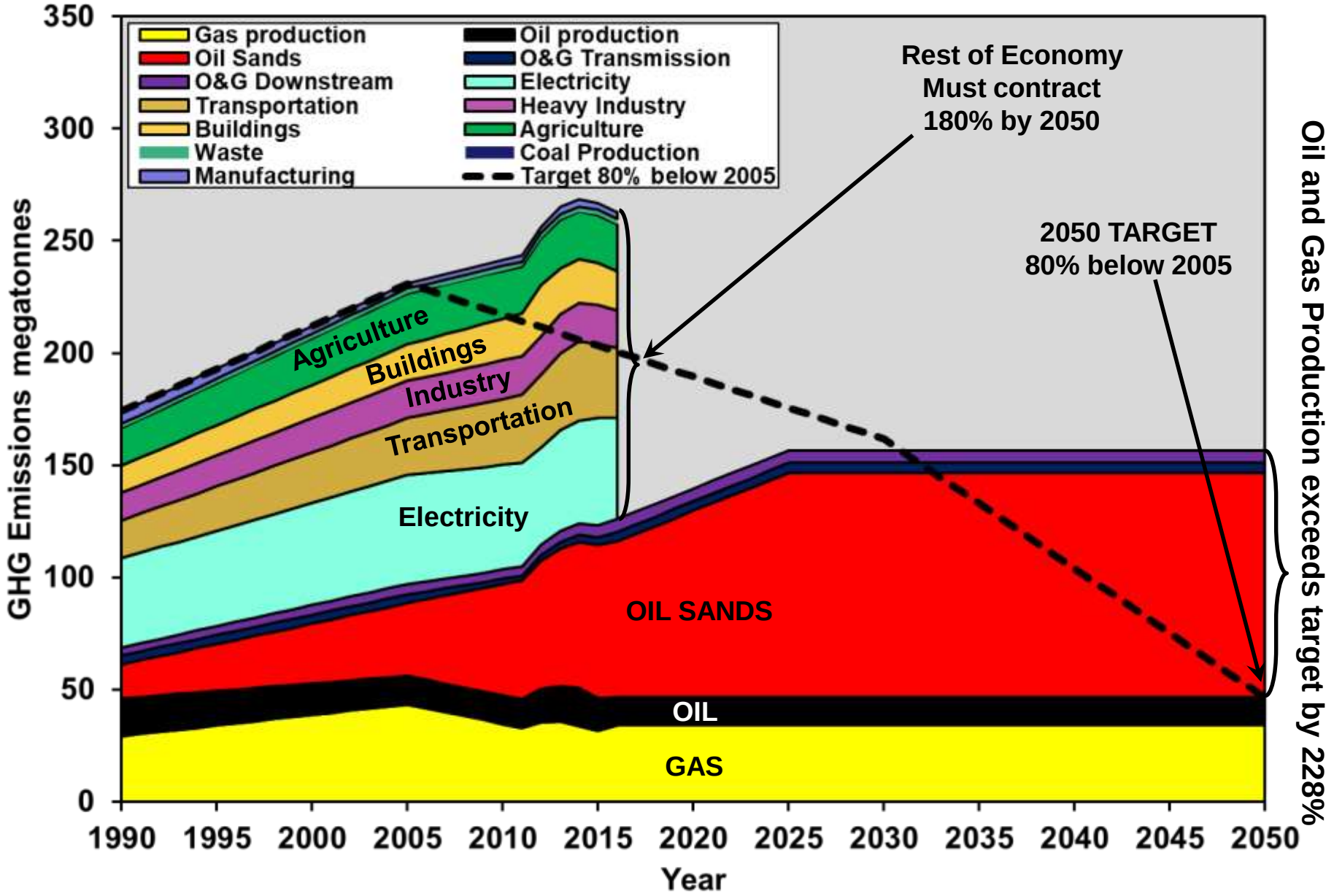
(data from ECCC UN NIR, 2018)

GHG Emissions in Alberta 1990-2016 with Alberta Climate Plan to 2030 – 100 Mt Oil Sands Cap and constant O&G



(data from ECCC UN NIR, 2018)

GHG Emissions in Alberta 1990-2016 with Climate Plan Aspirations to 2050 – 100 Mt Oil Sands Cap and constant O&G



(data from ECCC UN NIR, 2018)

Even though Alberta's Climate Action Plan is woefully insufficient, opponents would:

- Implement a fight-back strategy against environmental groups that want to limit production which will involve a war room in the department of energy, well-funded, to respond in real time.

- Cancel the carbon tax.

- Cut off oil shipments to BC as it opposes TMX.

- Boycott banks that shun fossil fuels.

- End equalization payments if pipelines are not built.

(from here and here)

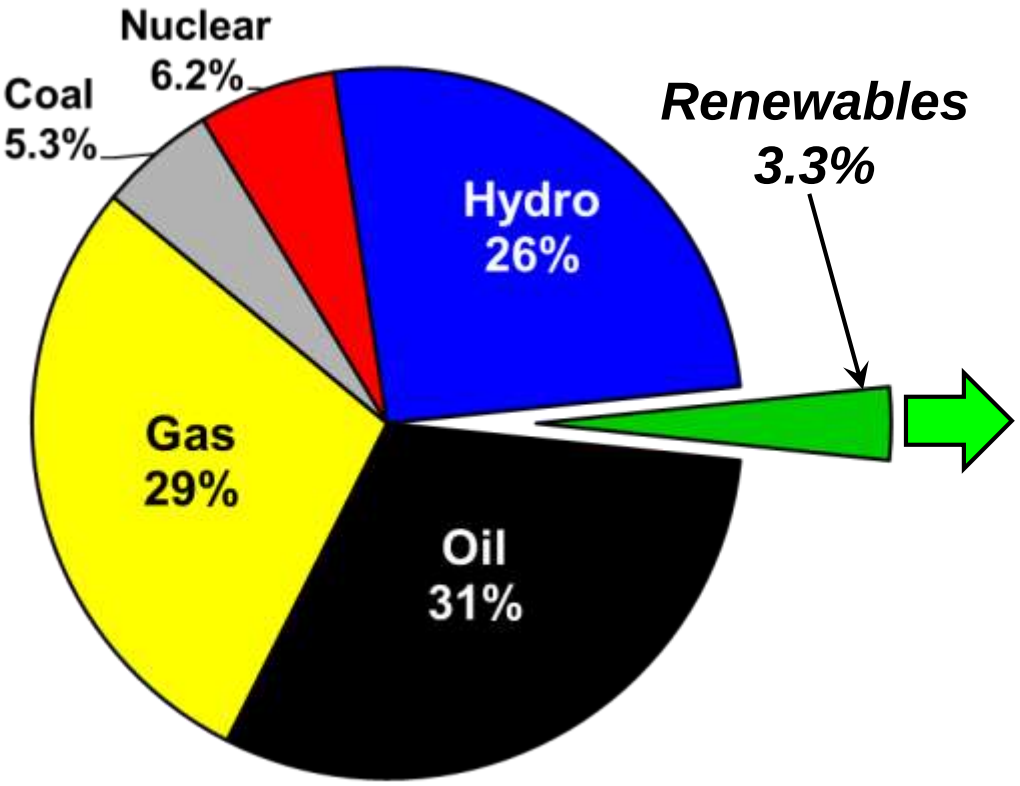
What Would it take to go 100% Renewable?

Several groups have plans e.g.:

- Jacobson, 2017
- Energy Watch Group, 2018
- DiCaprio Foundation, 2019

Canada Primary Energy Consumption by Source in 2017
A Comparison to Total Non-Hydro Renewable Energy

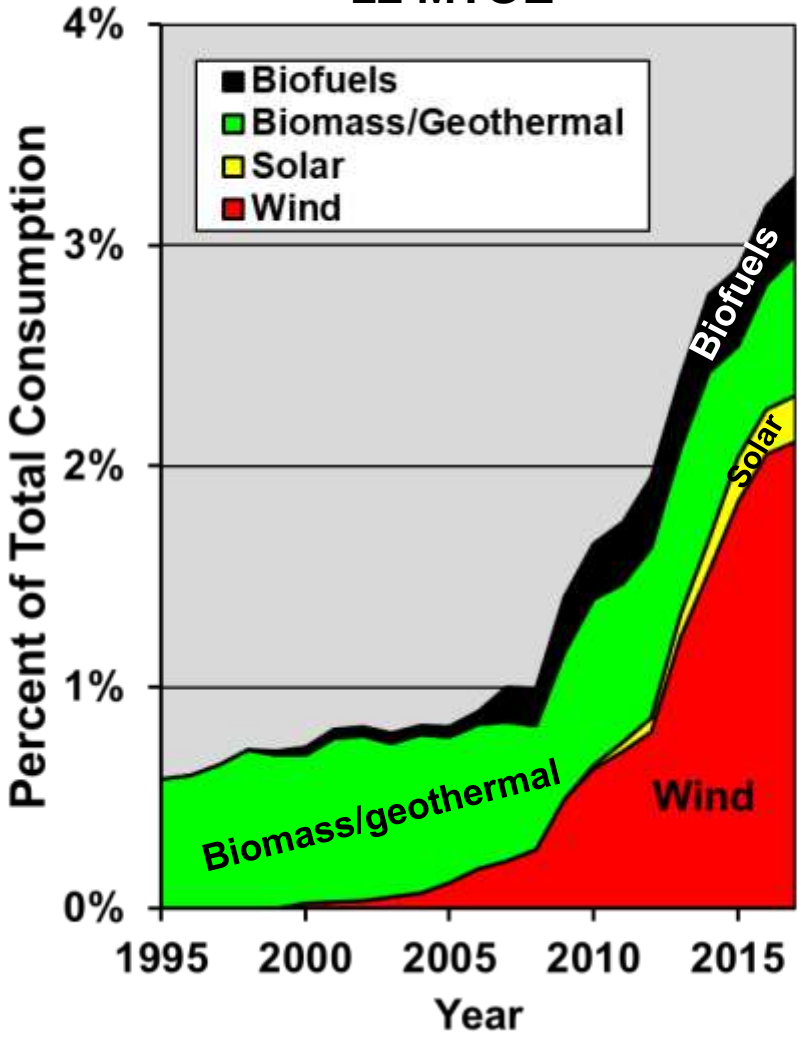
Total Energy by Source
349 MTOE



Large Hydro plus Renewables = 29%

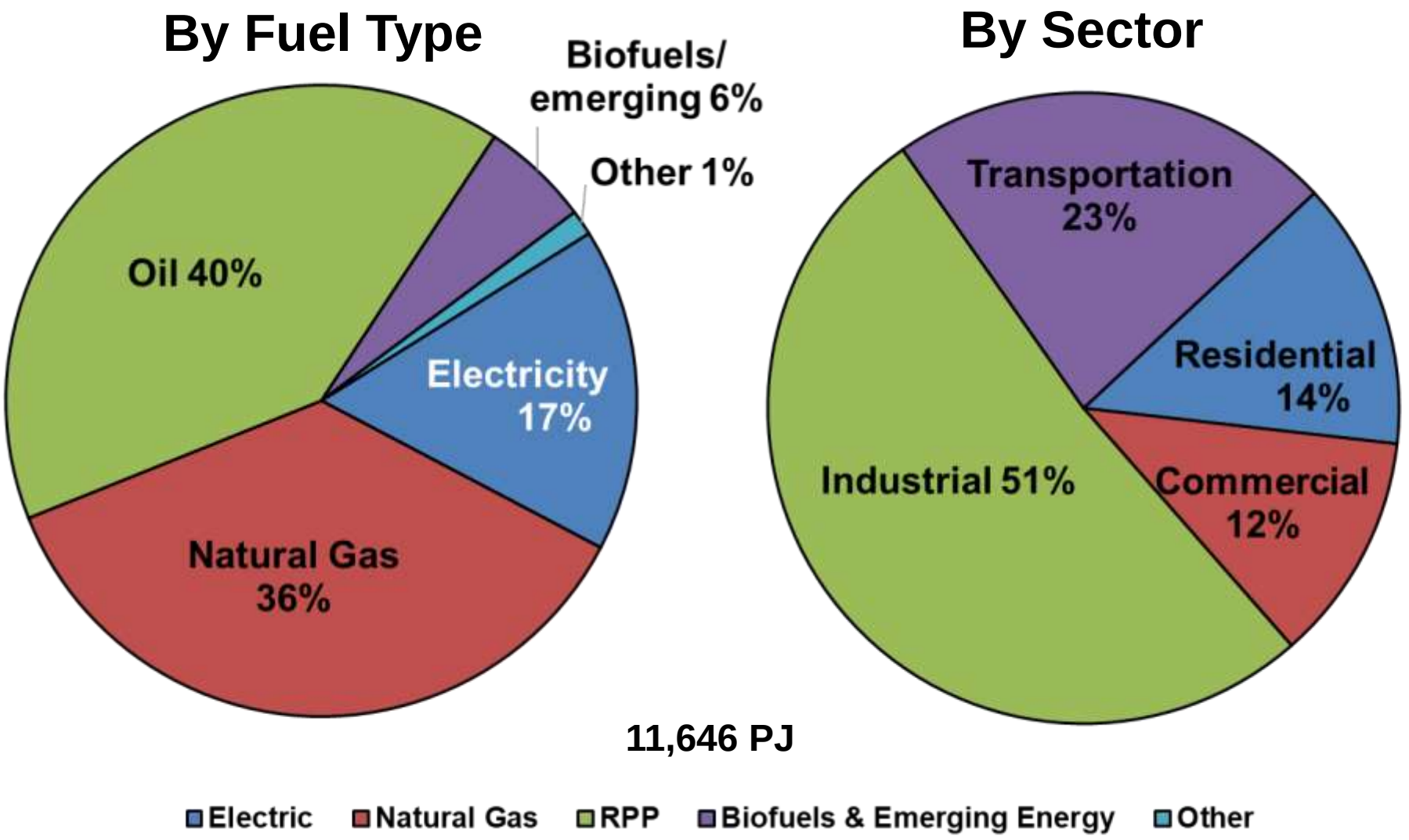
Total consumption has increased by 70% more than all 2017 non-hydro renewables since 2010

Renewable Energy by Source
12 MTOE



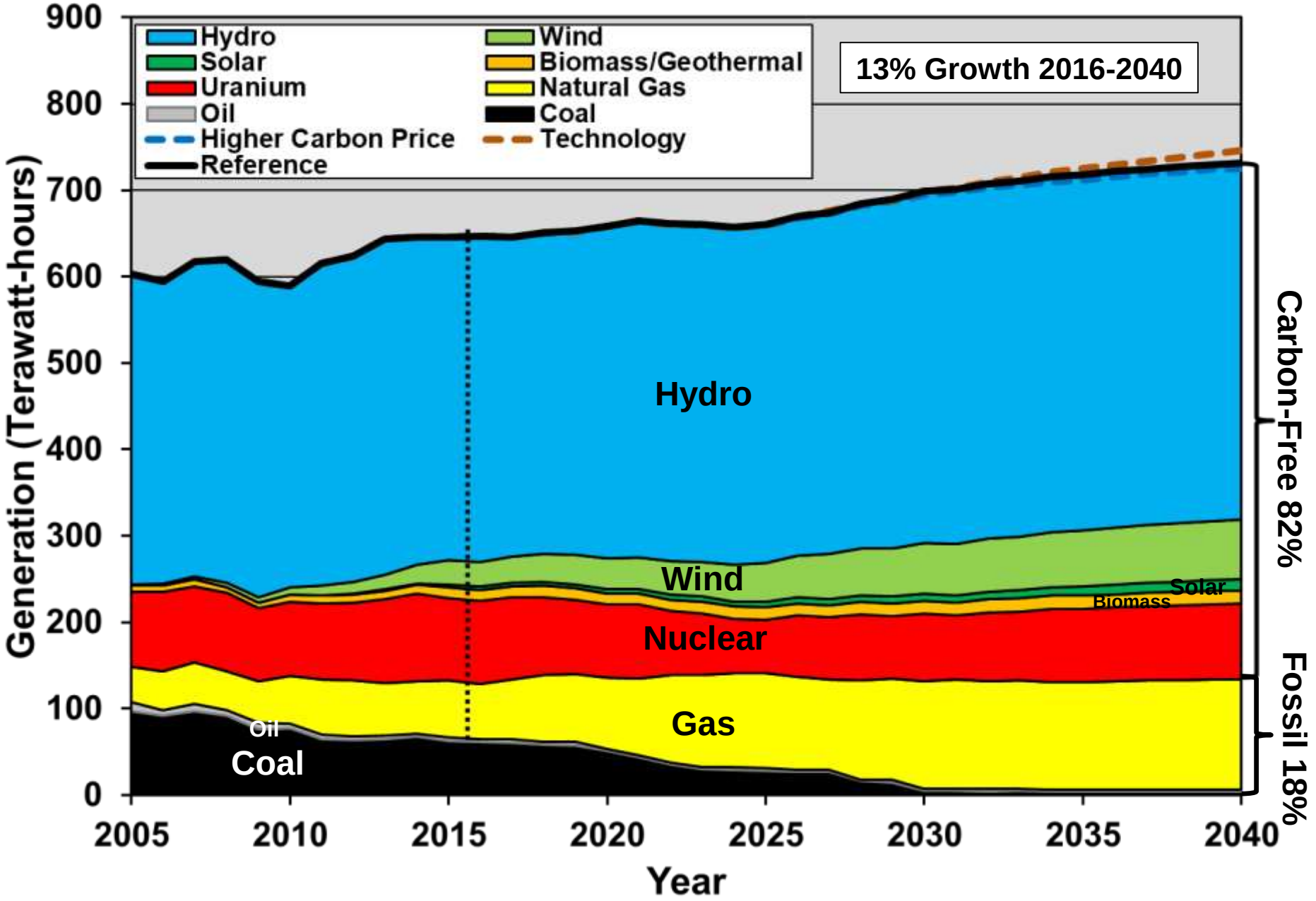
(data from BP Statistical Review of World Energy, 2018)

Canadian Delivered Energy by Type and Sector in 2017



(data from National Energy Board 2017, Reference case)

Electricity Generation by Source, 2005 - 2040



(data from NEB Energy Future 2017)

The Intermittency of Renewable Sources like Solar and Wind presents challenges:

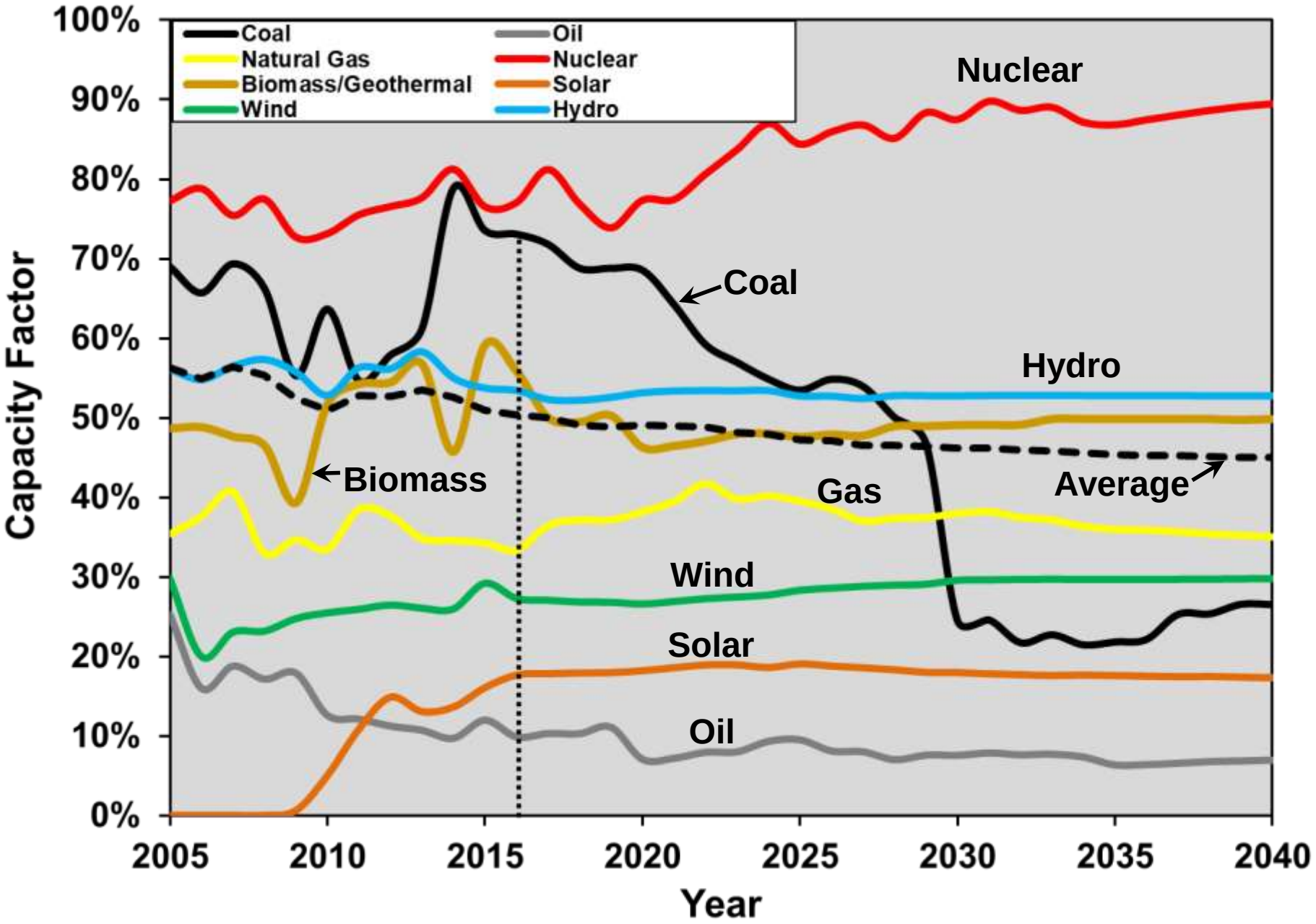
- Without sufficient storage for times with no wind or seasonal and daily fluctuations in output, one needs to overbuild capacity resulting in curtailment of output when the sun is shining and the wind is blowing.

- To avoid curtailment one either needs massive amounts of storage through things like batteries or pumped hydro, or dispatchable backup fuel sources like natural gas or biomass.

- Canada's large hydro resource also provides an excellent source of dispatchable backup for renewables.

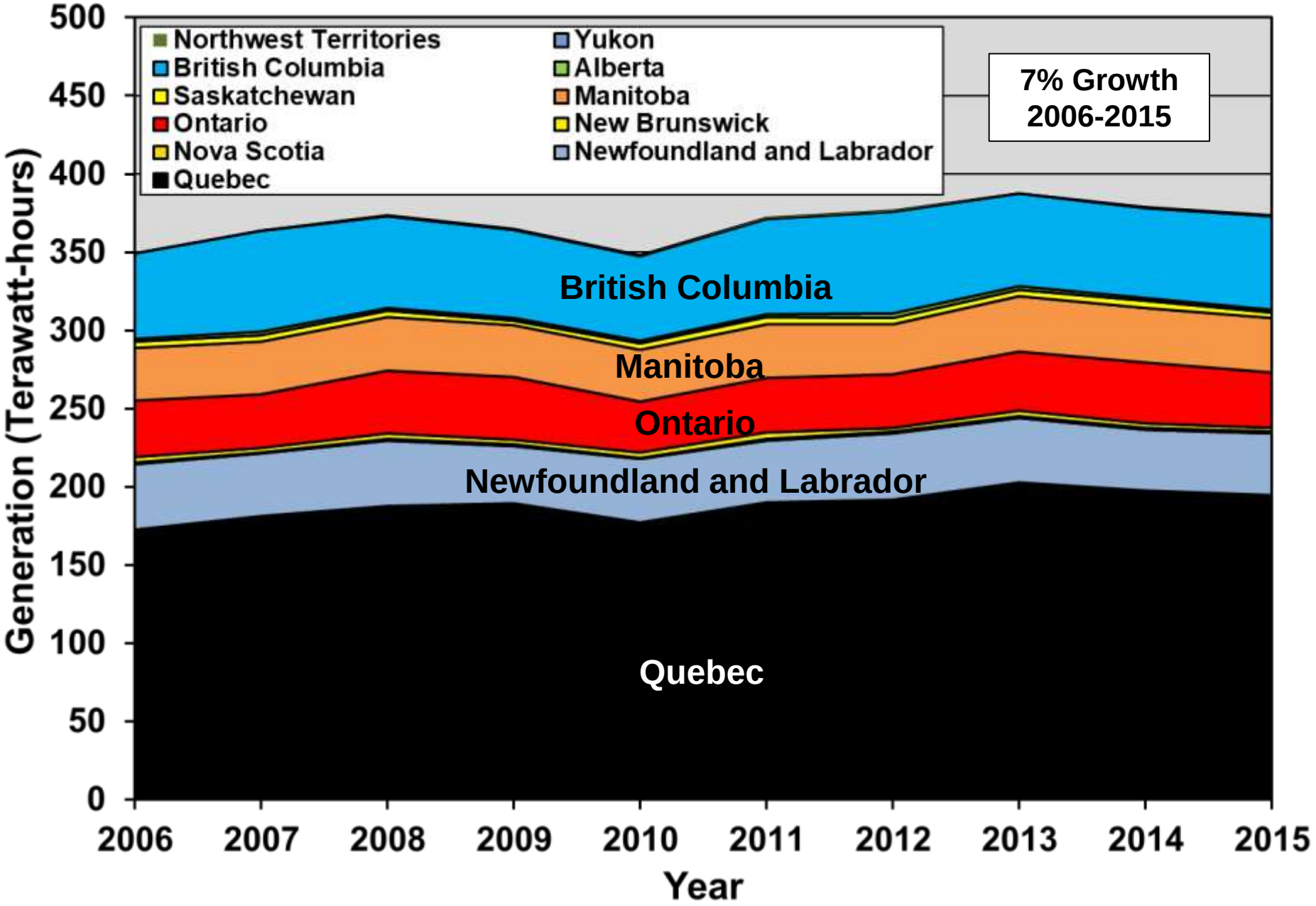
(from here and here)

Capacity Factor by Electricity Source, 2005 - 2040



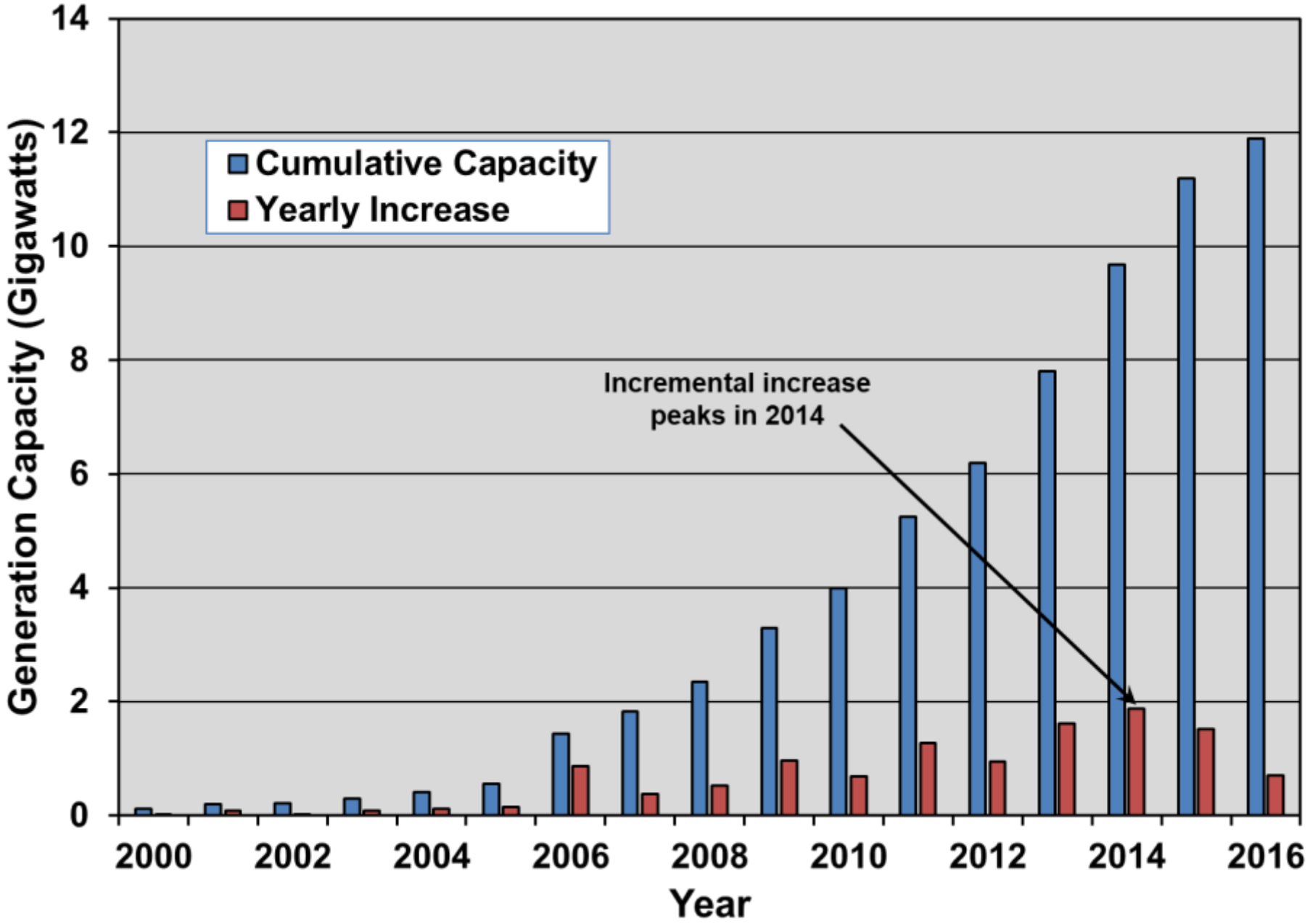
(data from NEB Energy Future 2017, reference case)

Hydro Generation by Province, 2006-2015



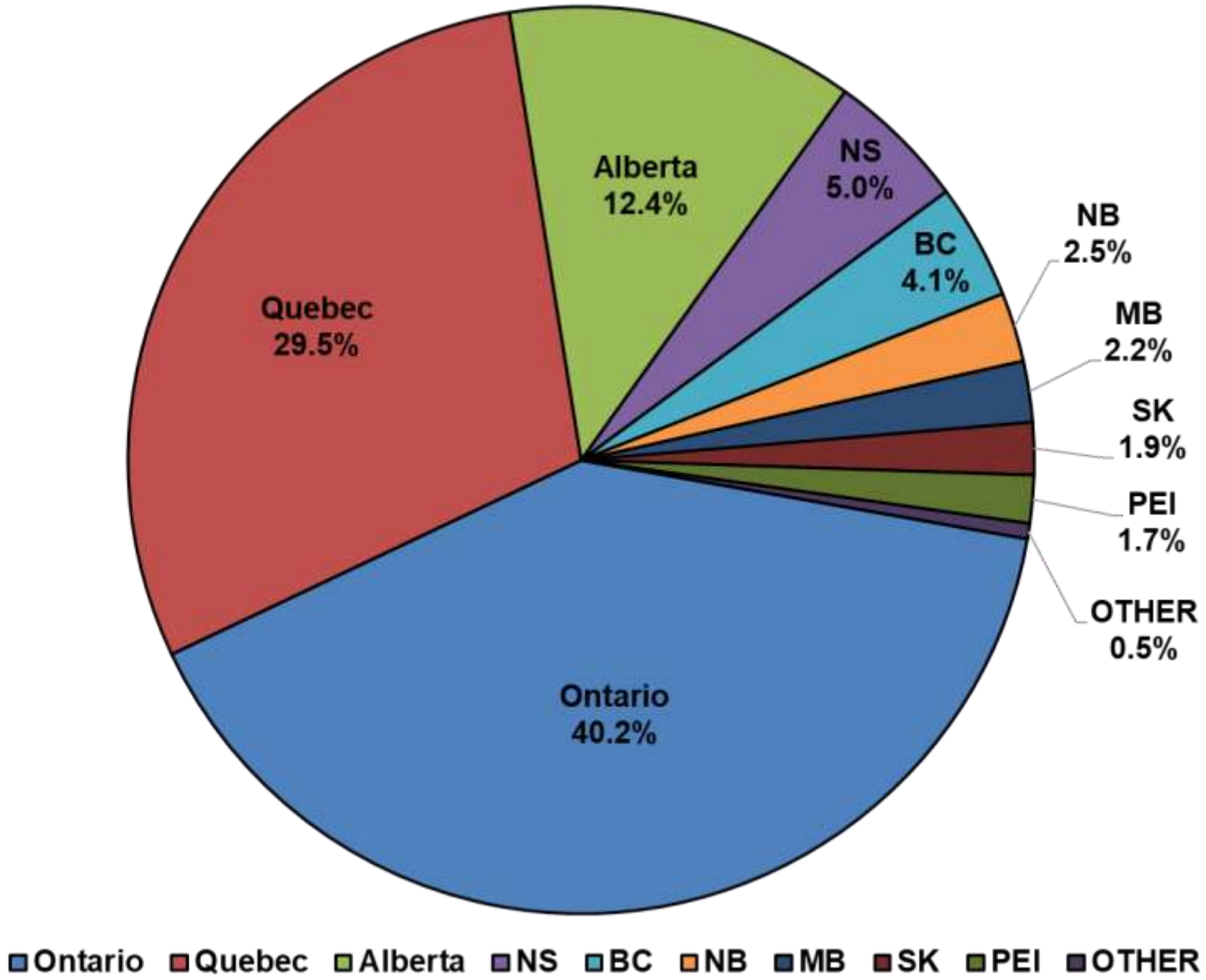
(data from Statcan 2017, Table 127-0007)

Canada Wind Generation Capacity, 2000-2016



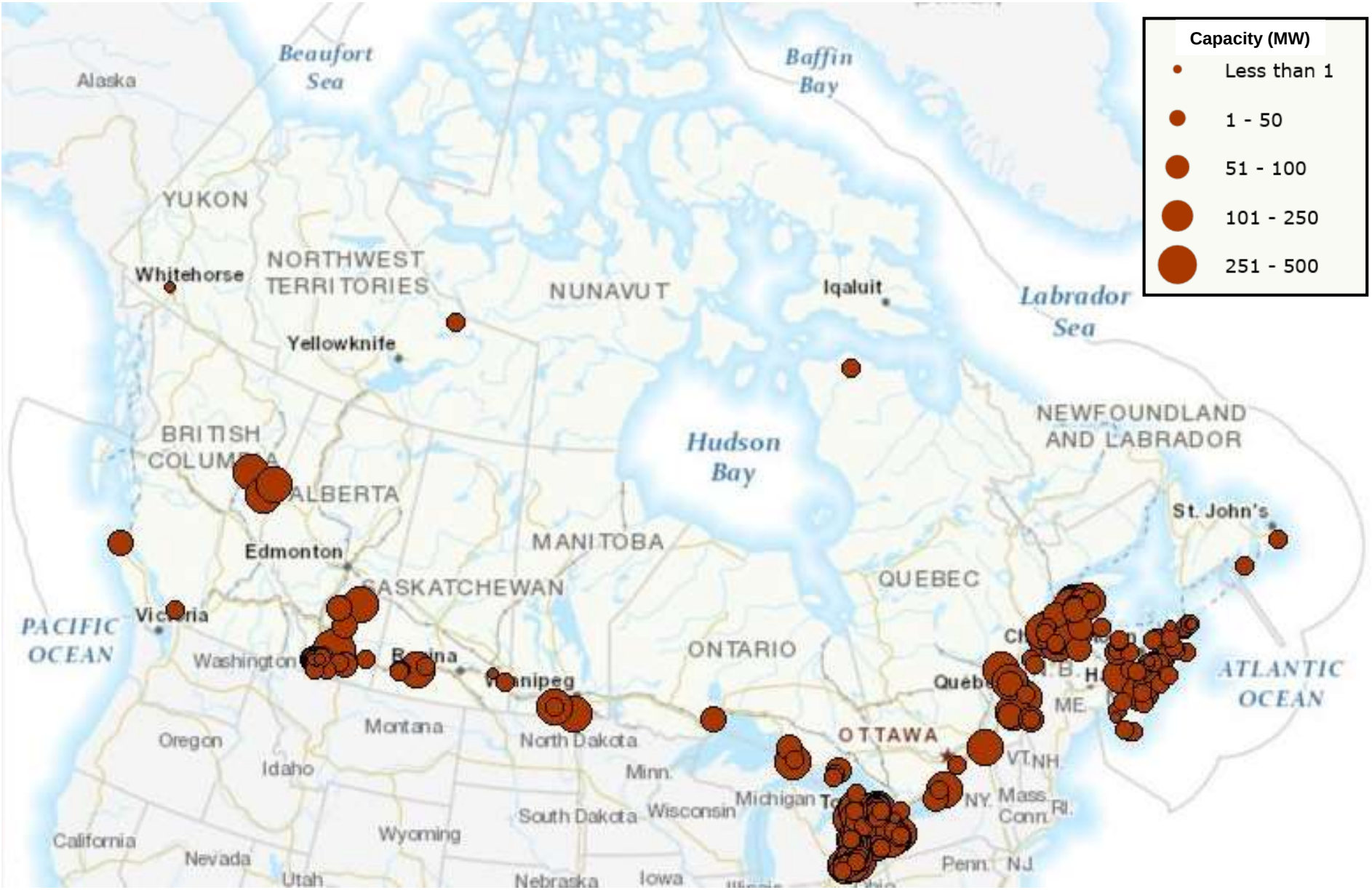
(data from Canadian Wind Energy Association, 2017)

Canada Wind Generation Capacity by Province in 2016



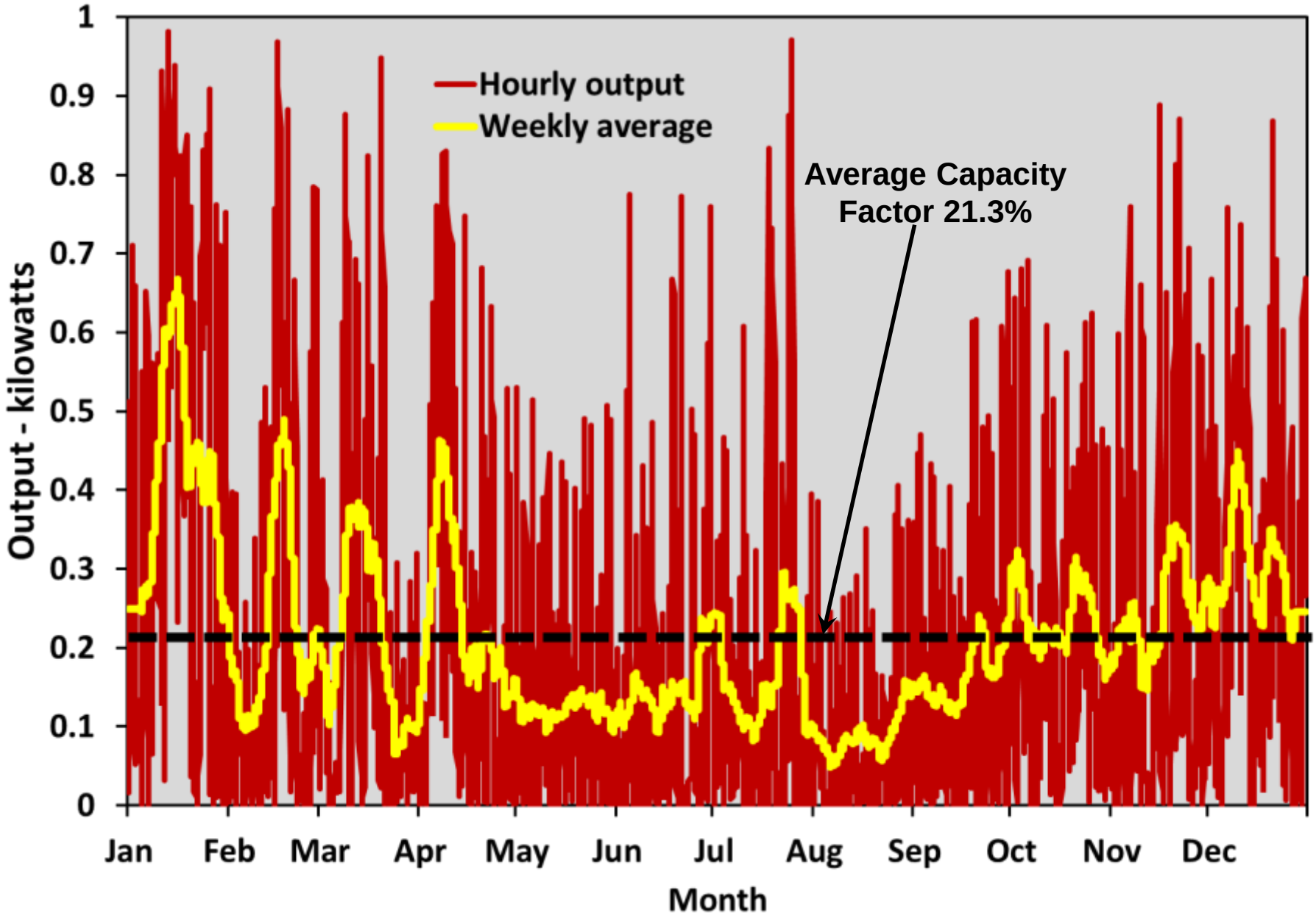
(data from Canadian Wind Energy Association, 2017)

Wind Generating Stations in Canada (11,058MW)



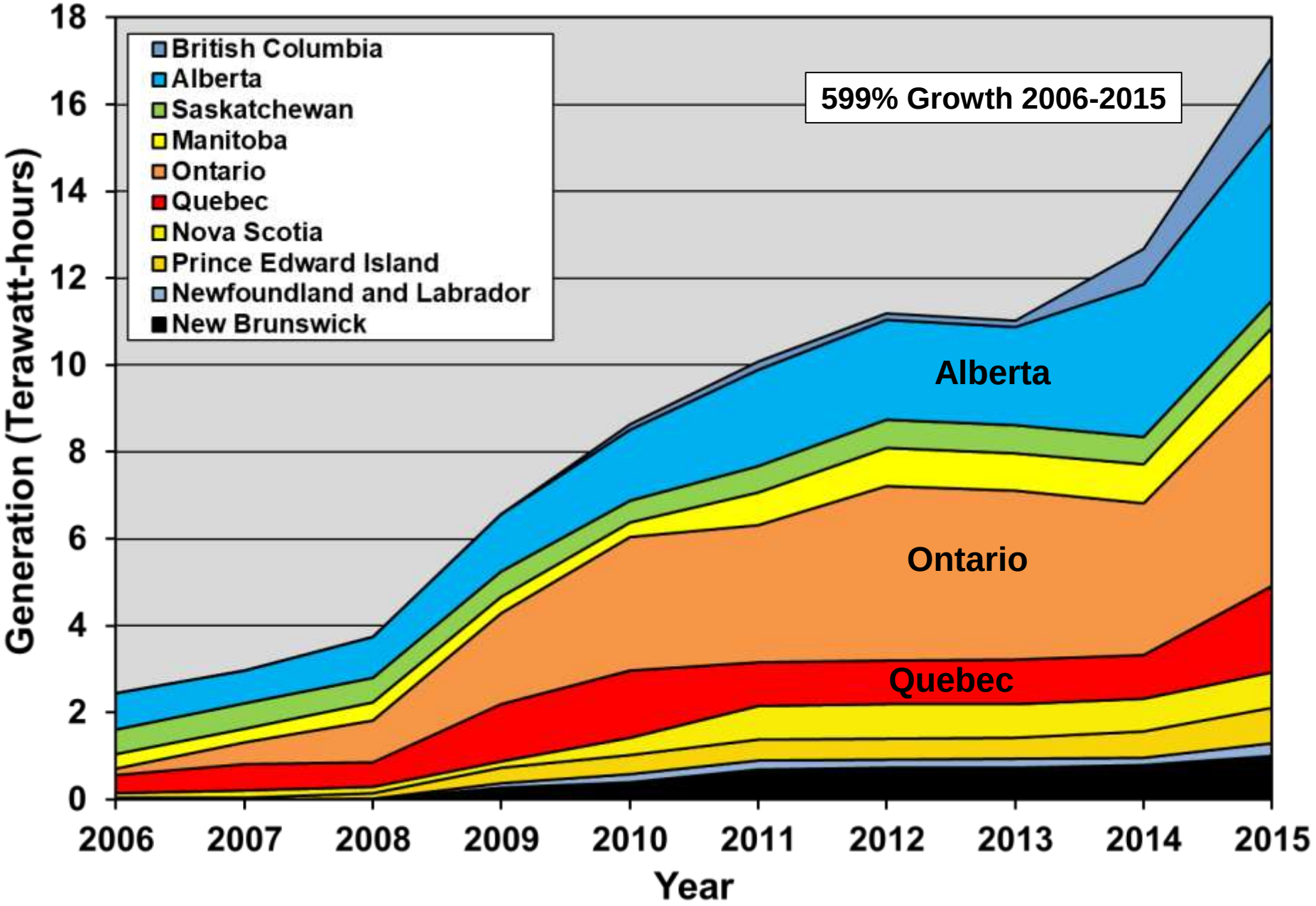
(data from NRCan Atlas of Canada, June 10, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Generation per Kilowatt at Calgary in 2014 – 60 metre tower



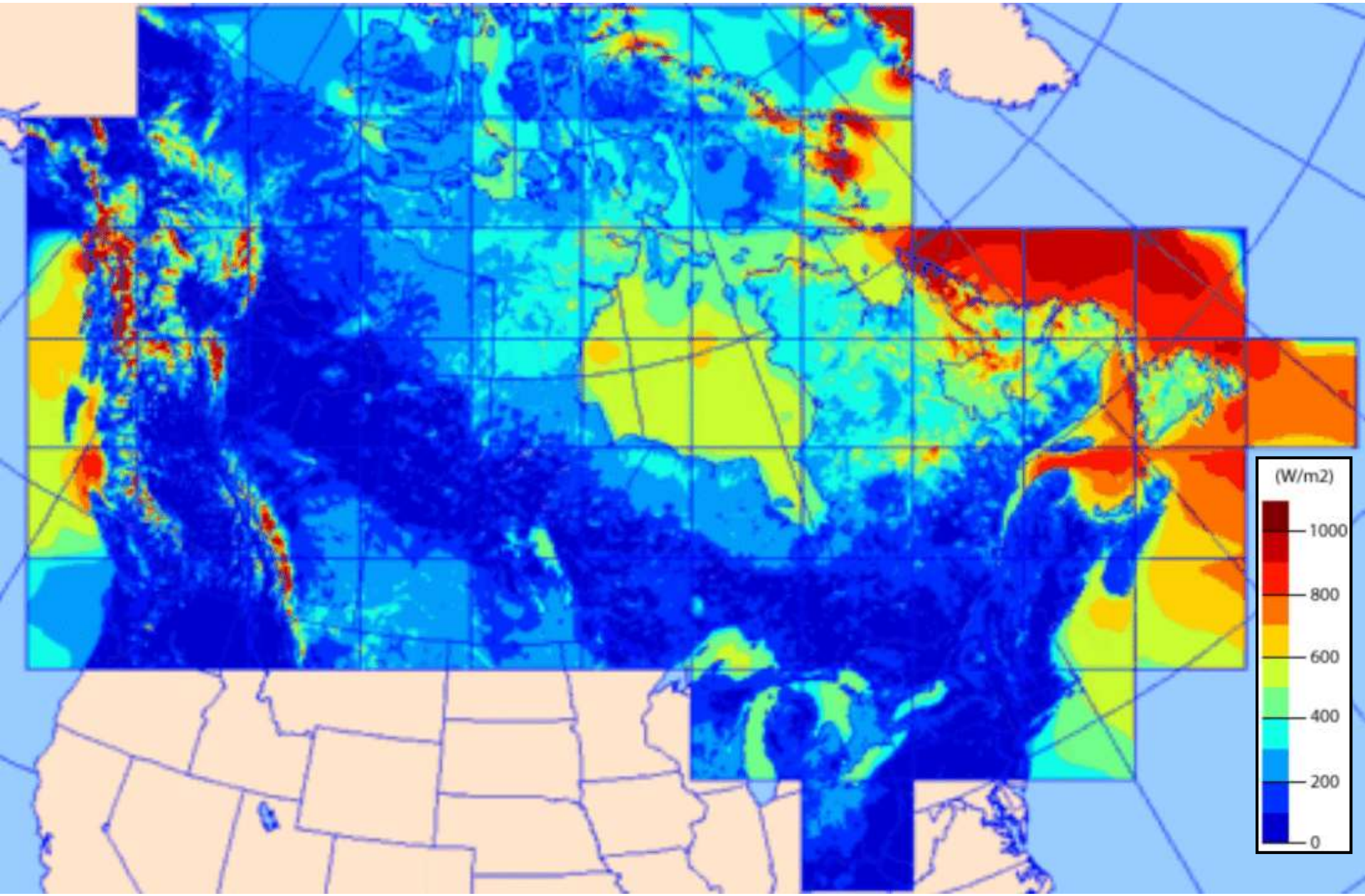
 (data from NASA Merra-2 database with bias-correction from Staffell and Pfenninger, 2016 – Vestas V80-2000)

Wind Generation by Province, 2006-2015



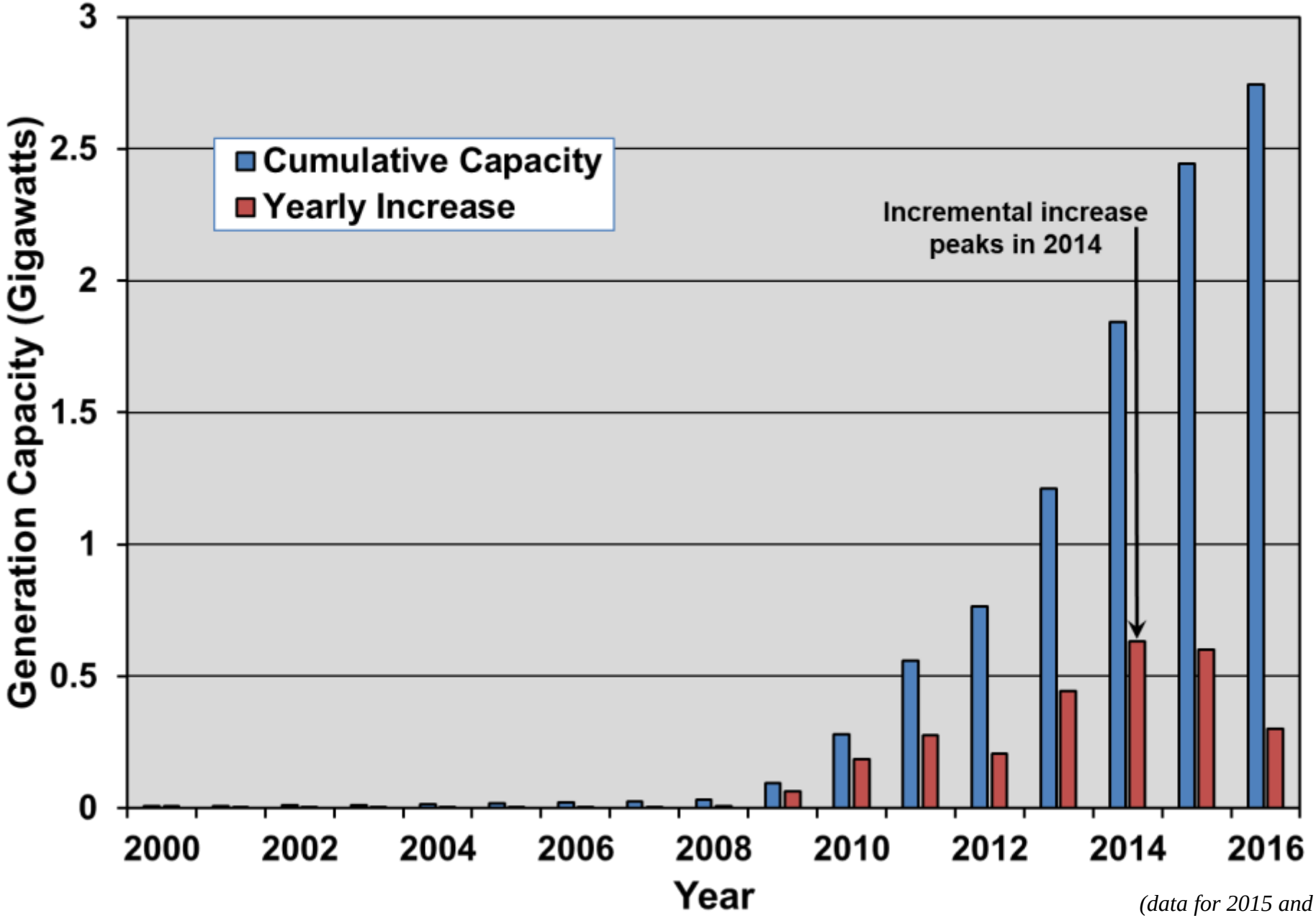
(data from Statcan 2017, Table 127-0007)

Wind Energy Potential in Canada



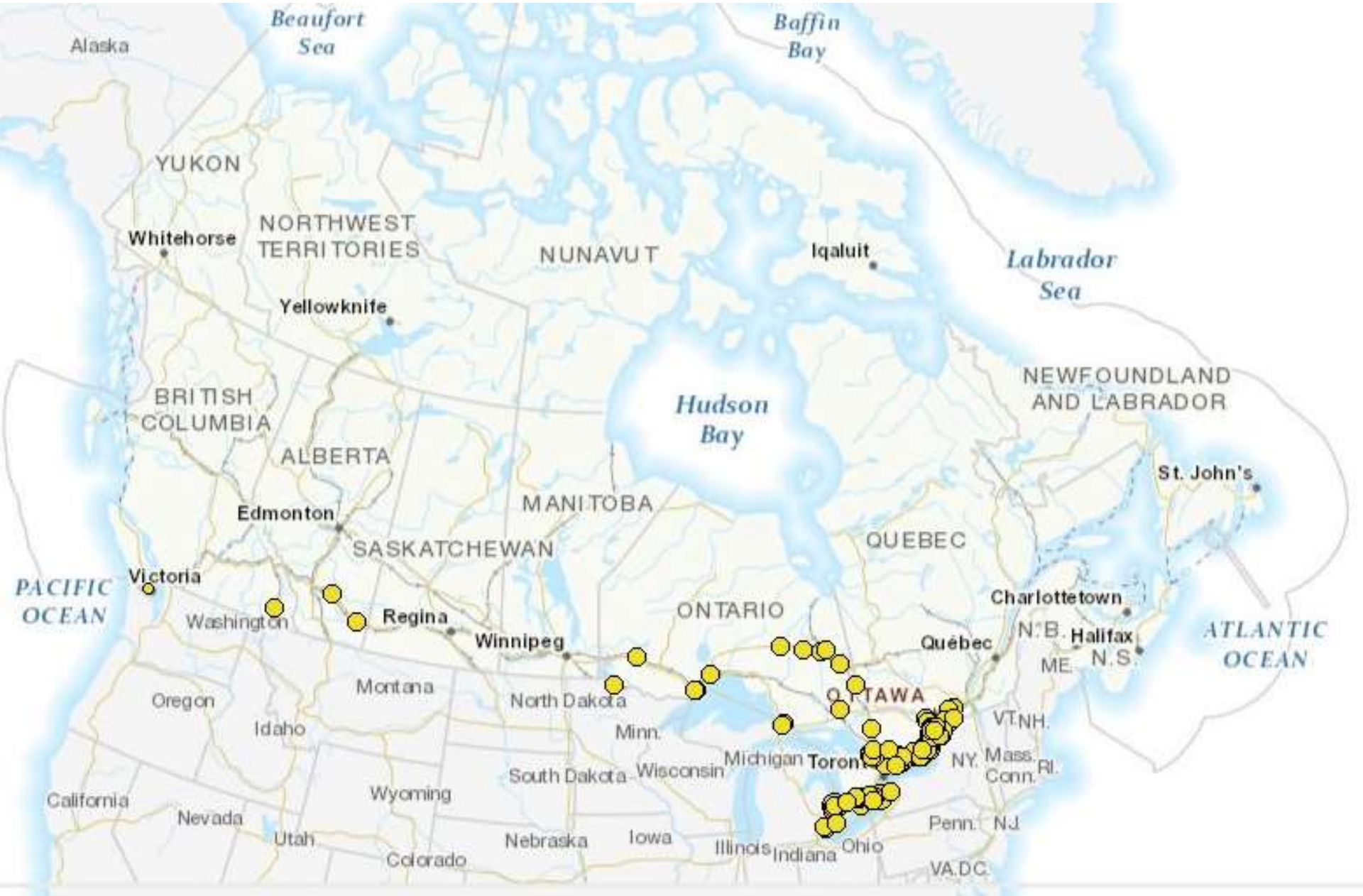
(data from Canadian Wind Energy Atlas, June 10, 2017, http://www.windatlas.ca/)

Canada Solar Generation Capacity, 2000-2016



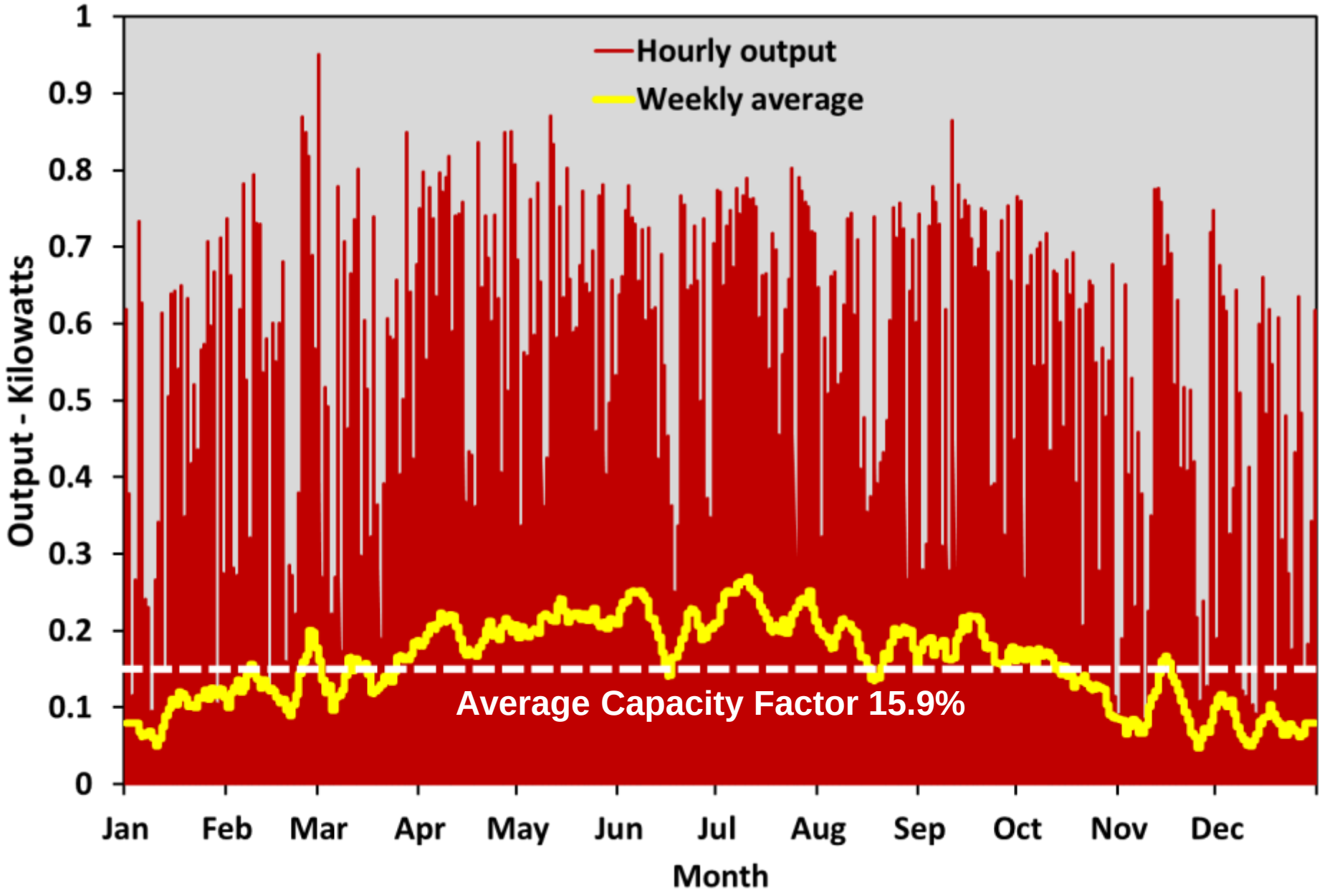
(data for 2015 and 2016 from IRENA, 2017;2000-2014 data from NRCan National Survey Report of PV Power Applications in Canada 2014)

Large Scale Solar Projects in Canada (1,585MW)



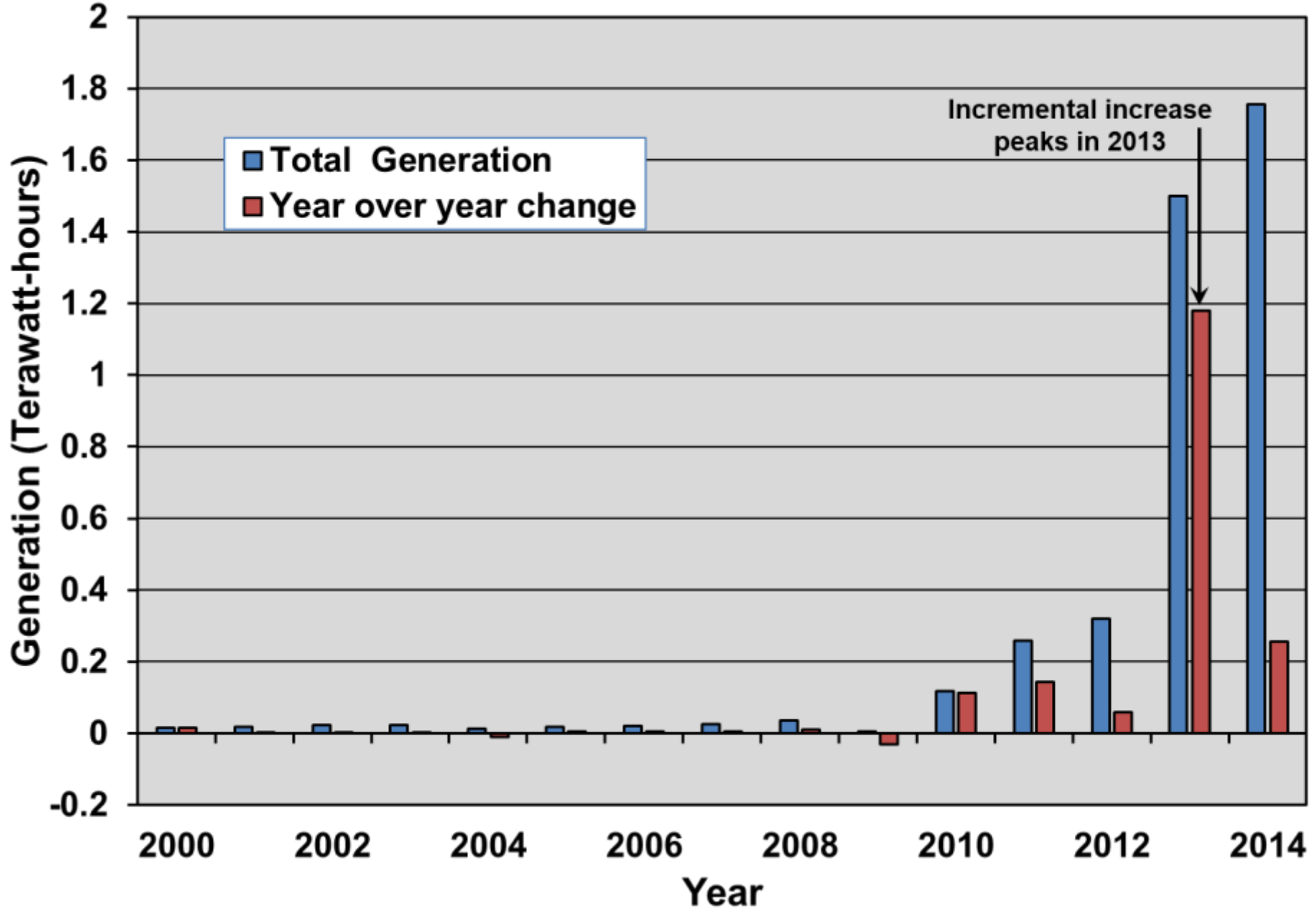
(data from NRCan Atlas of Canada, May 24, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Solar at Calgary in 2014 – 1000 watt panel



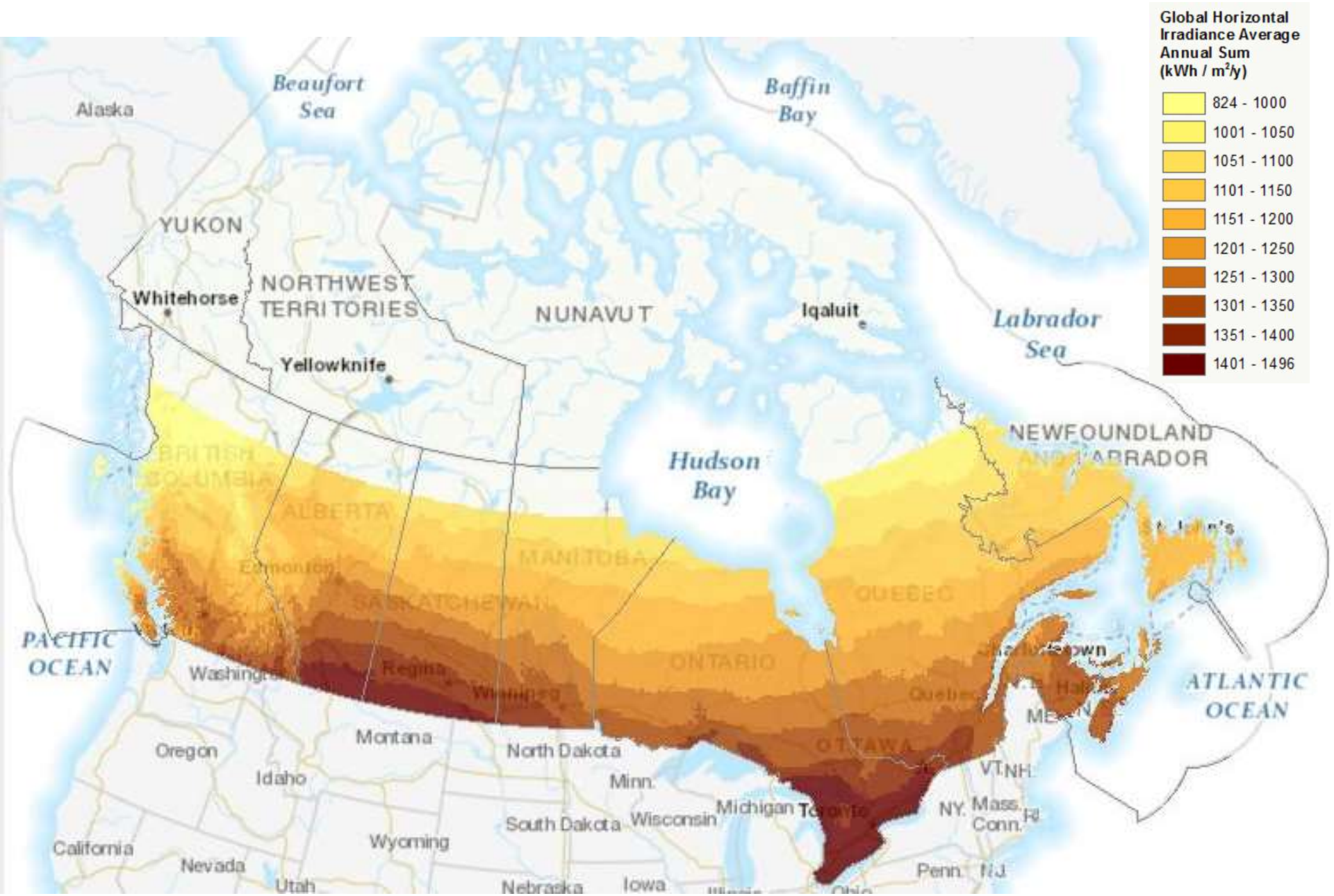
(data from NASA Merra-2 database with bias-correction from Staffell and Pfenninger, 2016)

Canada Solar Generation, 2000-2014



(data from IRENA April 25, 2017)

Solar Potential in Canada

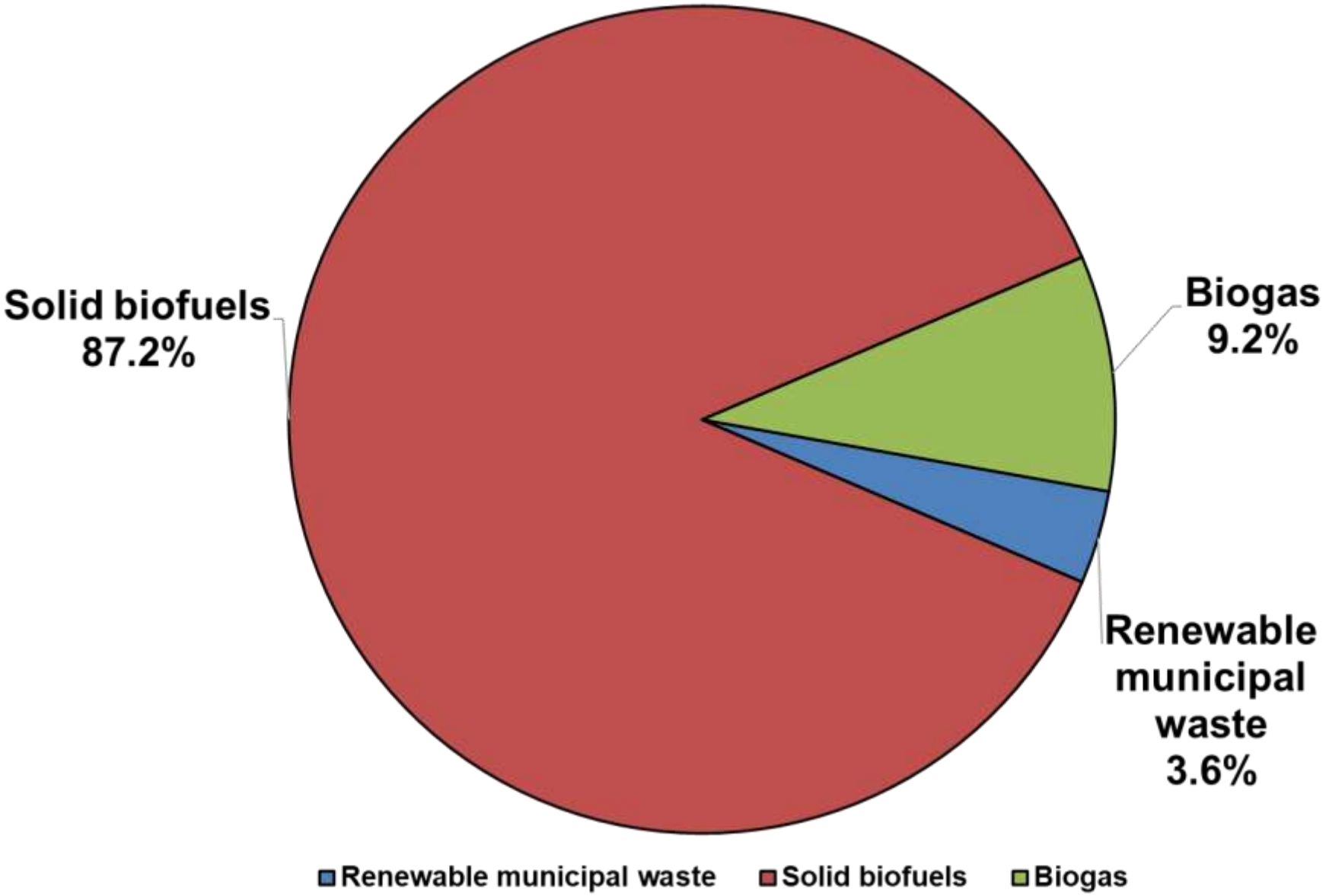


(data from NRCan Atlas of Canada, May 24, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Biomass Generating Stations in Canada (2,843MW)

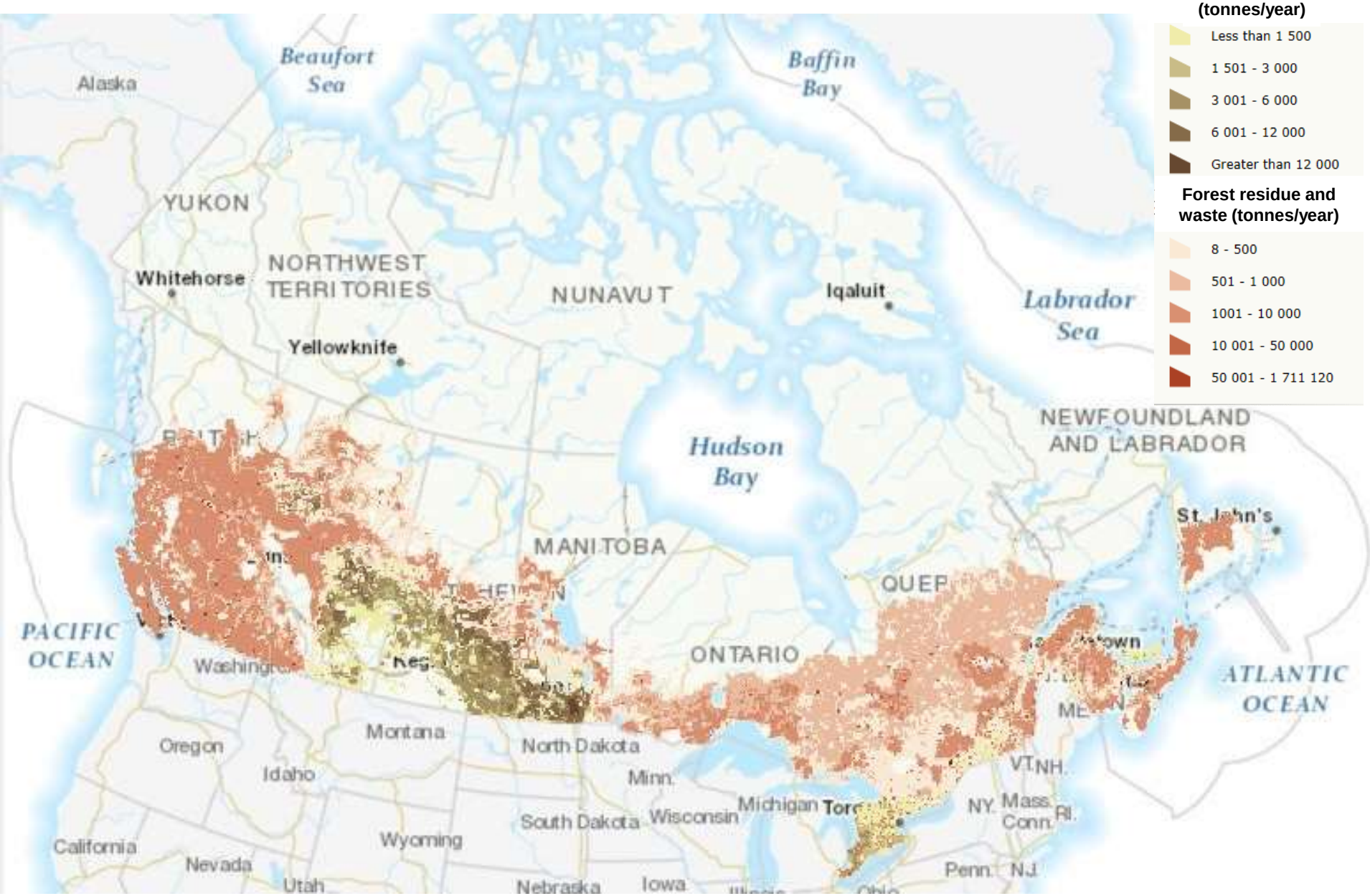
(data from NRCan Atlas of Canada, May 24, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Canada Biomass Generation Capacity by Fuel Type in 2016



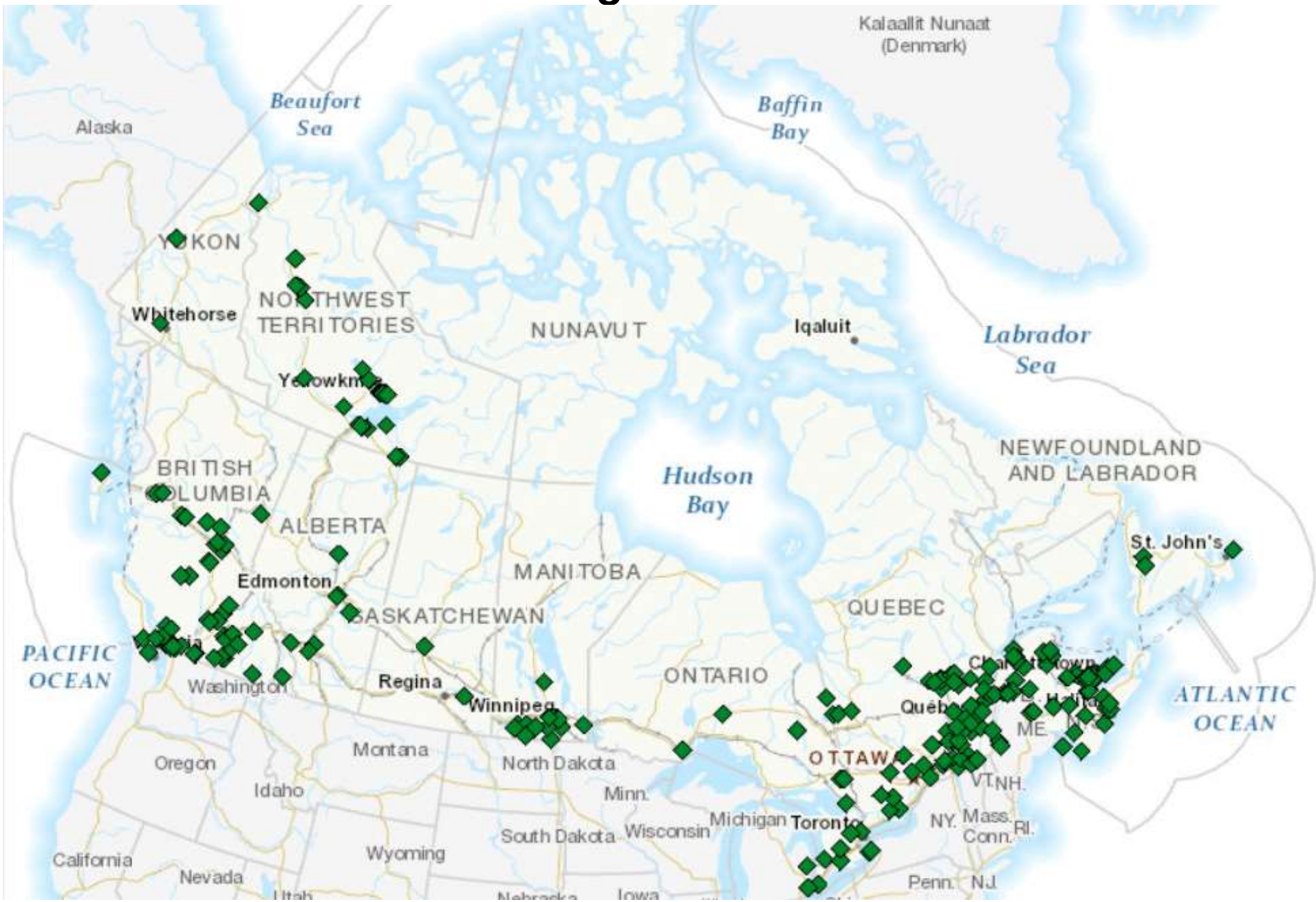
(data from IRENA, 2017)

Biomass Potential in Canada



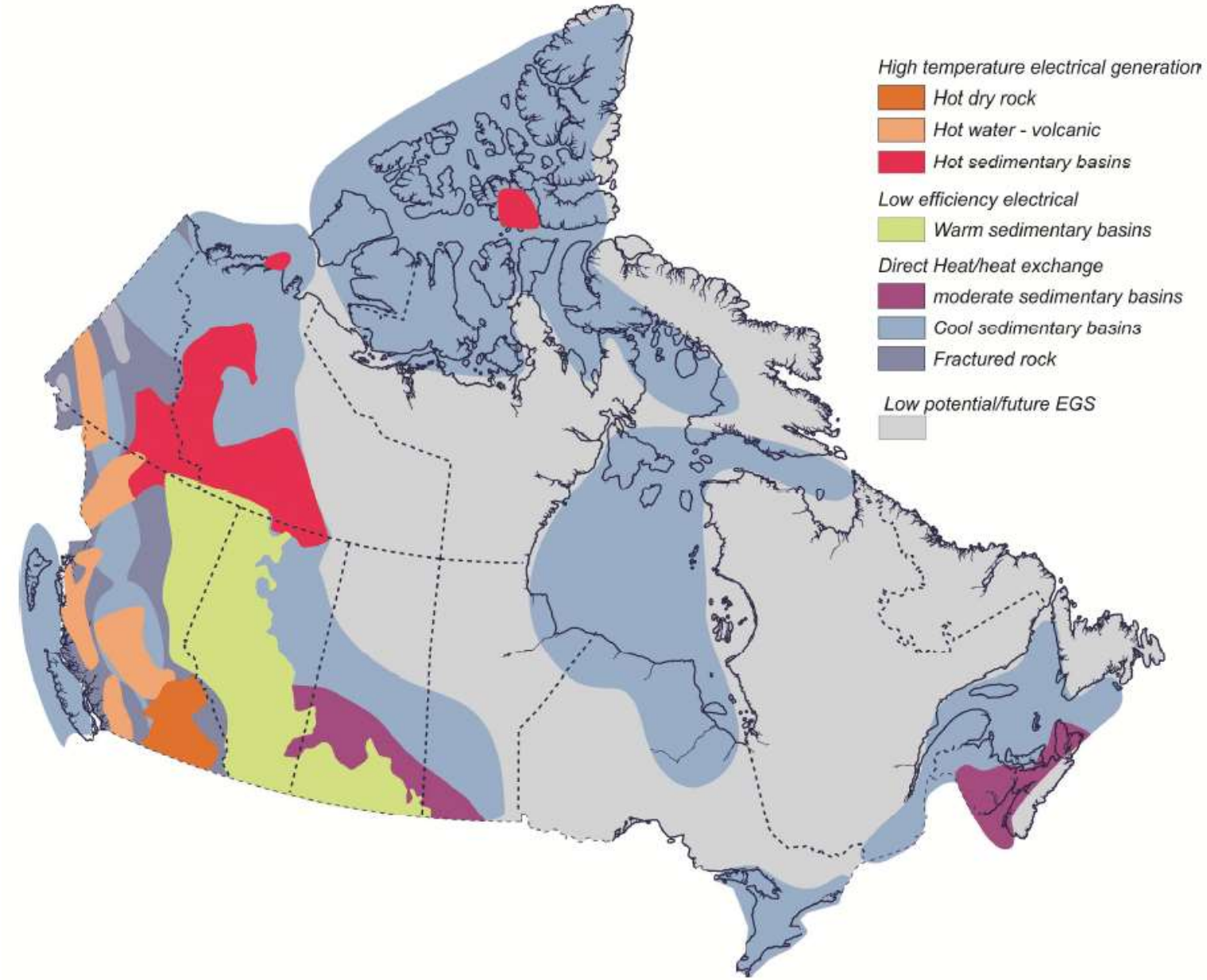
(data from NRCan Atlas of Canada, May 24, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Biomass Heating Facilities in Canada



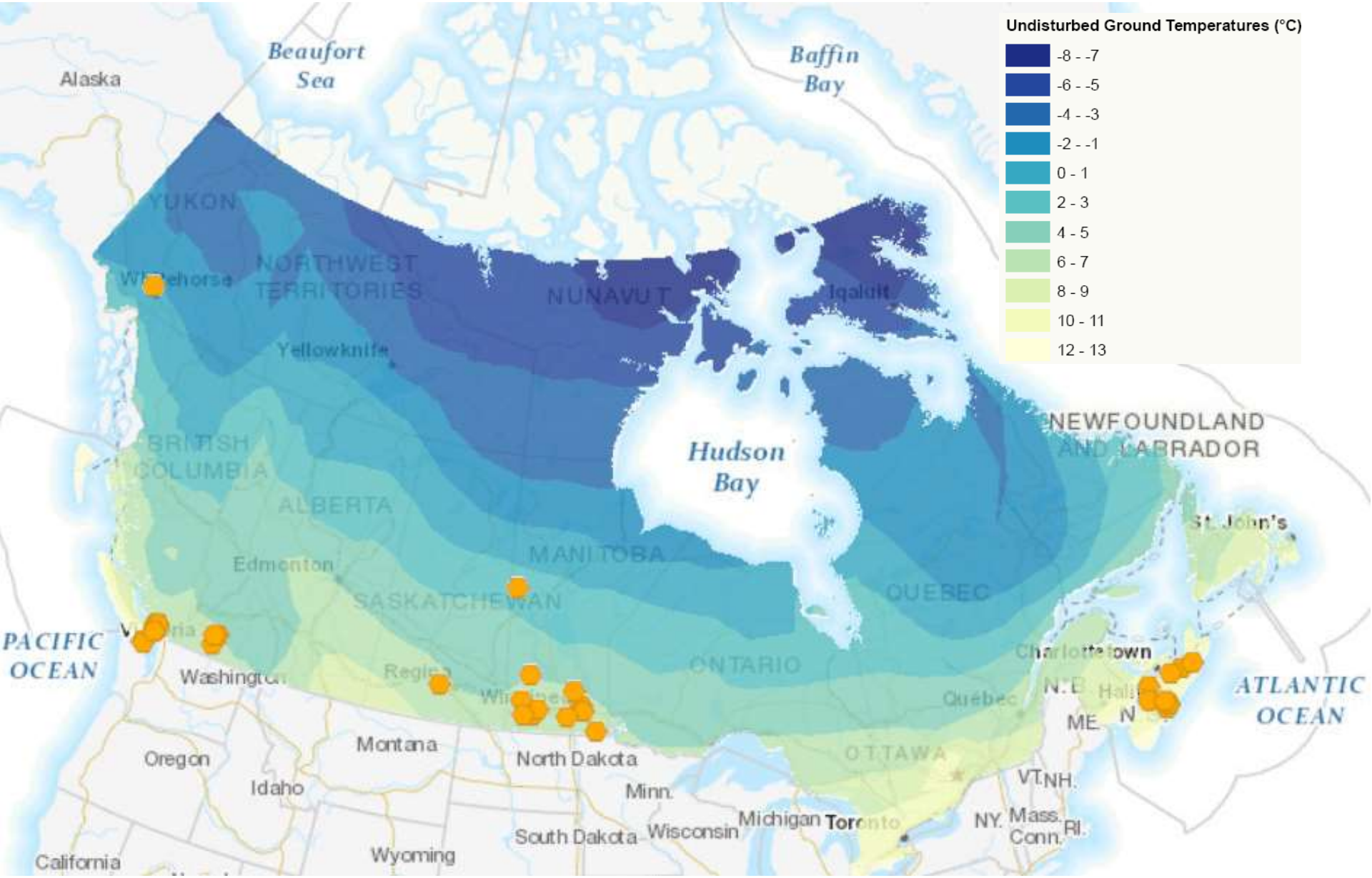
(data from NRCan Atlas of Canada, June 29, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Geothermal Potential in Canada



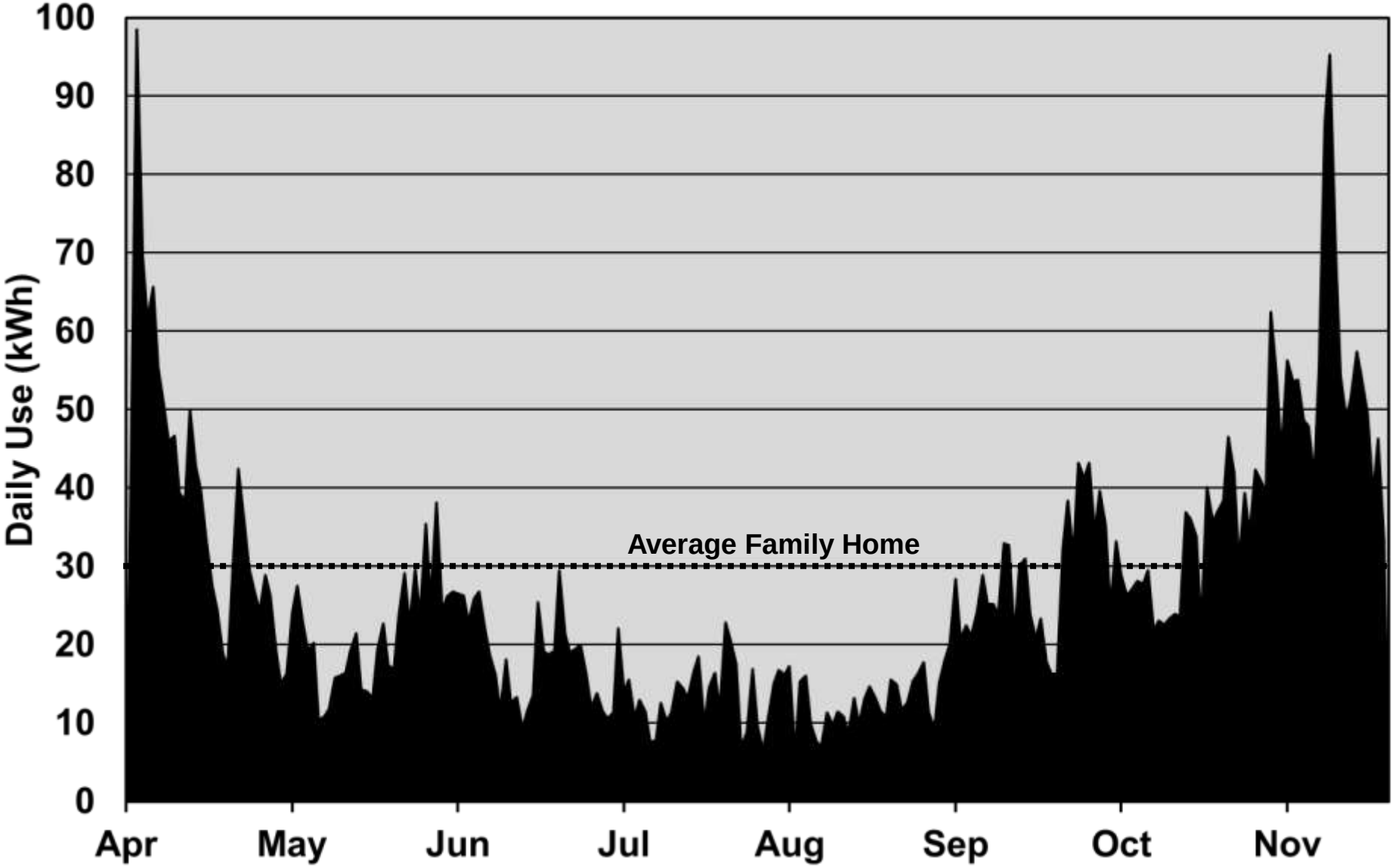
 (from Grasby et al., 2012, http://publications.gc.ca/collections/collection_2013/rncan-nrcan/M183-2-6914 eng.pdf

Geothermal Heating Potential in Canada



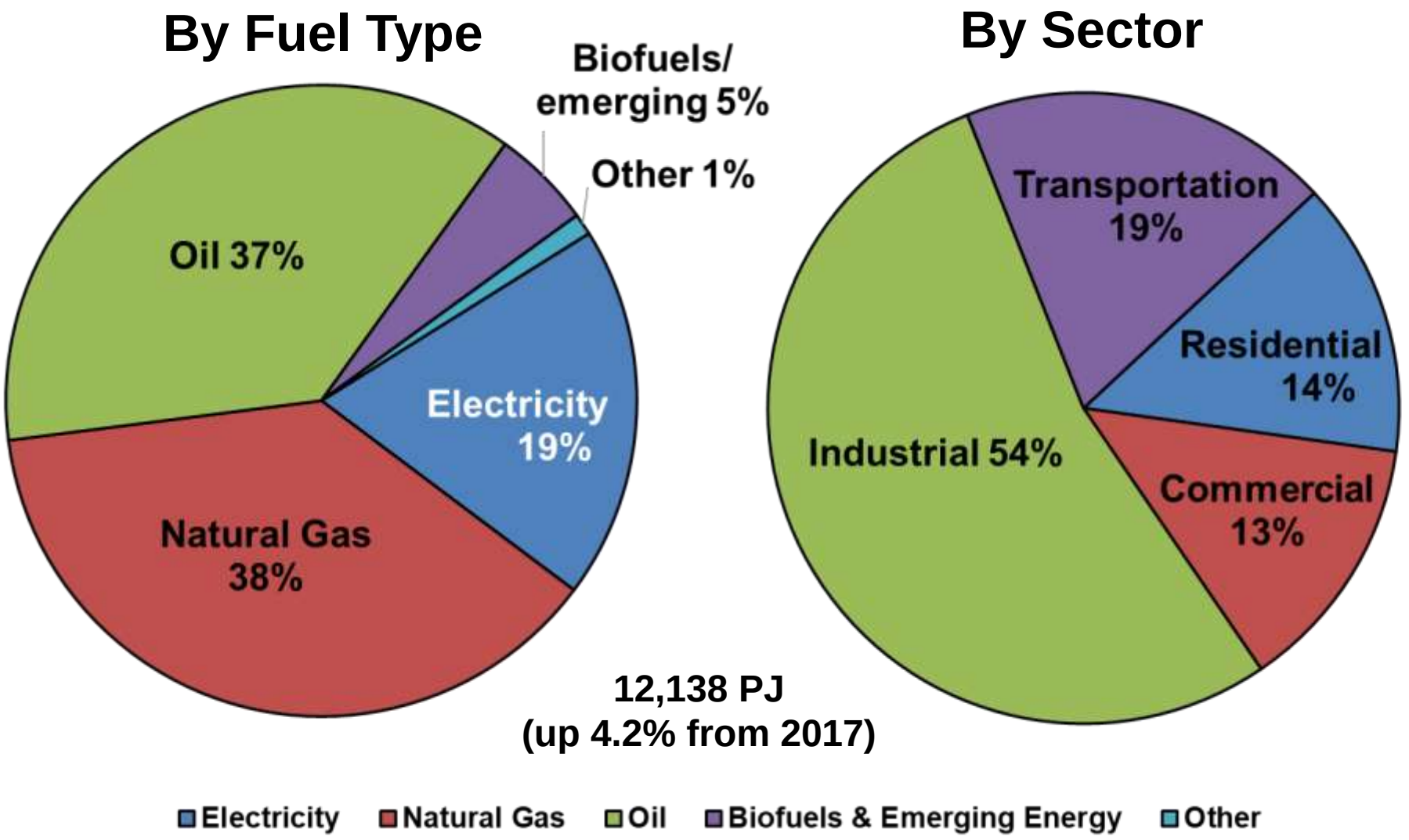
(data from NRCan Atlas of Canada, June 24, 2017, http://atlas.gc.ca/cerp-rpep/en/)

Heat – Air Source Heat Pump on West Coast (Mild Canadian Climate)



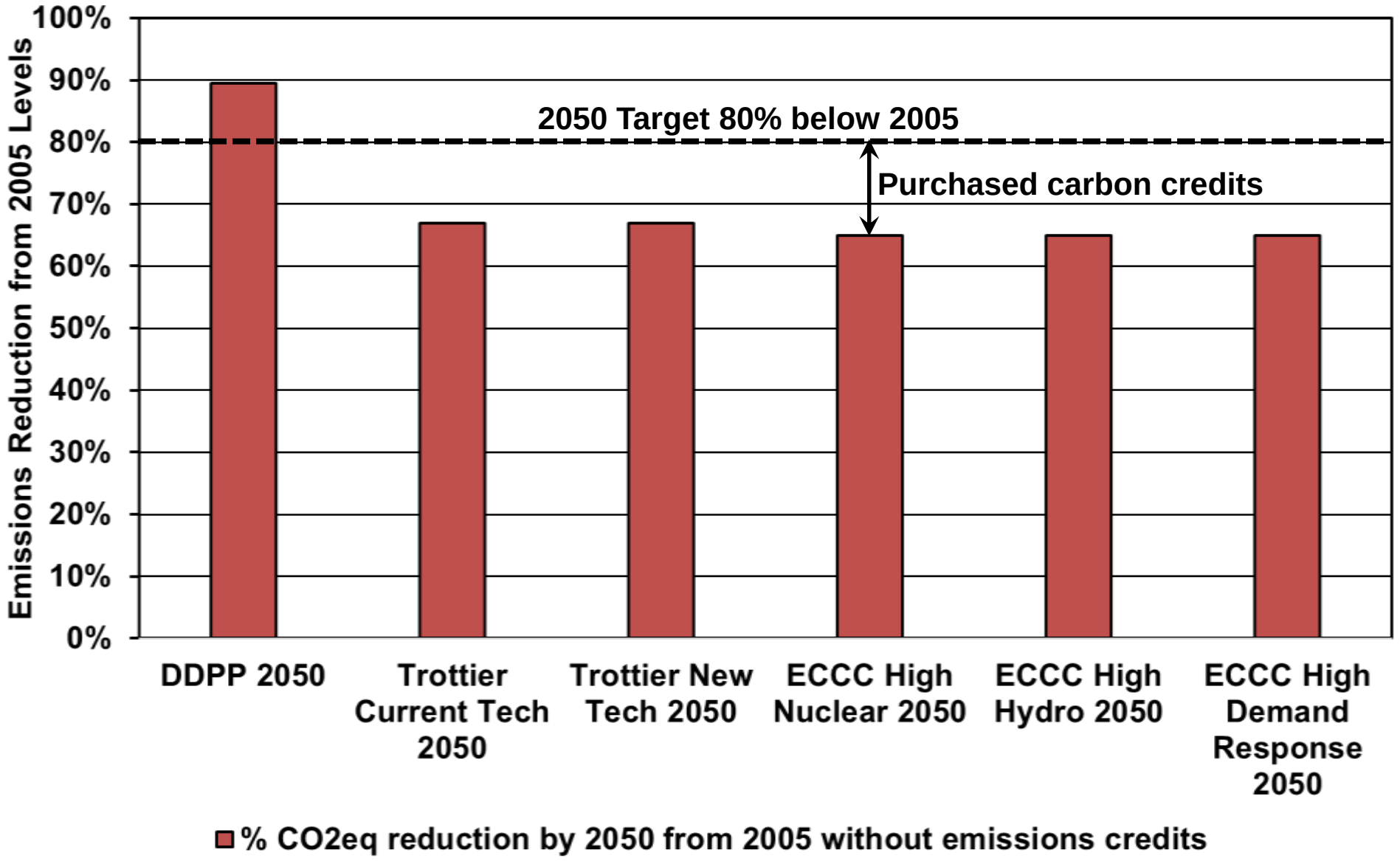
(data from BC Hydro December, 2018)

Canadian Delivered Energy by Type and Sector in 2040



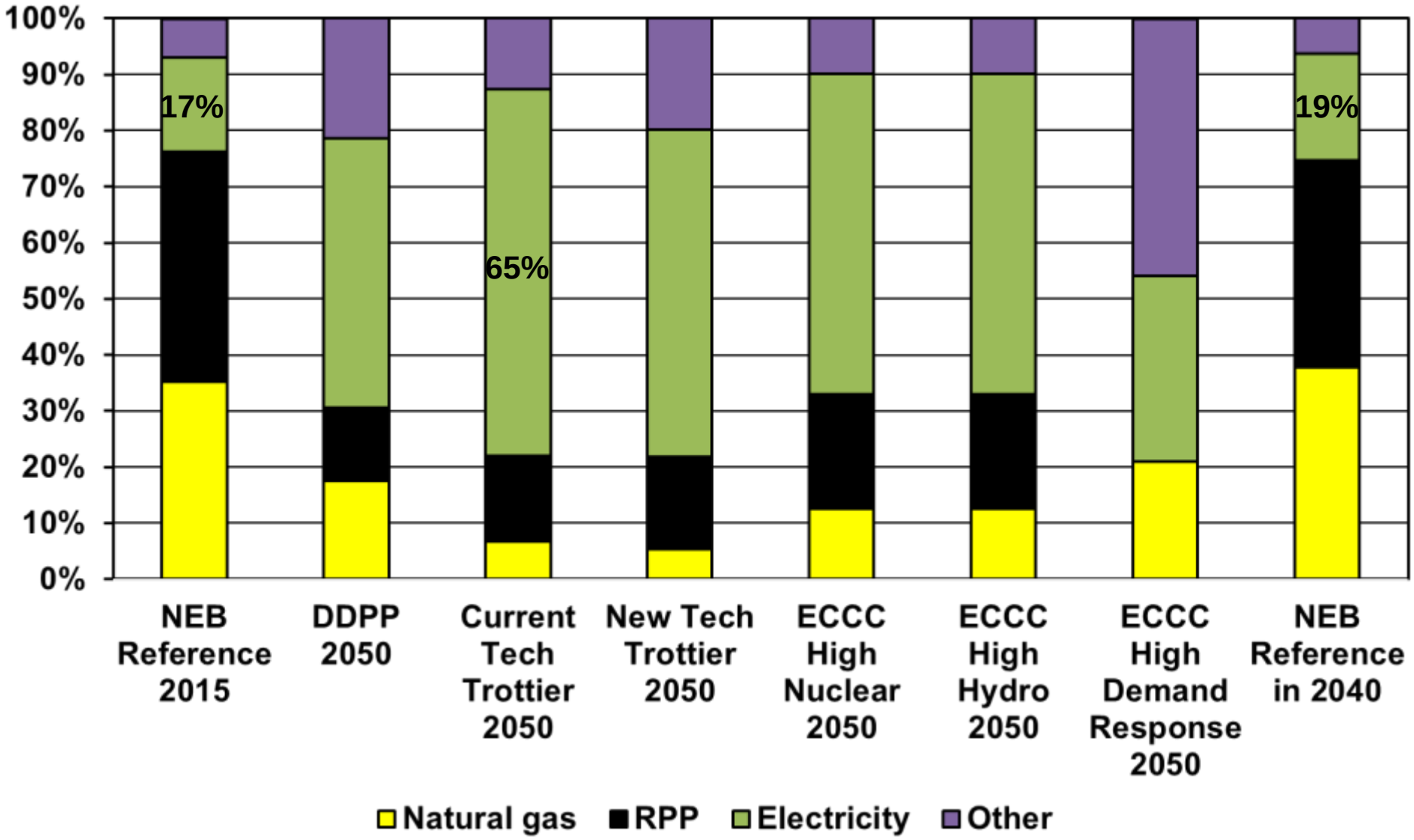
(data from National Energy Board Energy Future 2017, Reference case)

Reduction in Emissions from 2005 levels by 2050 in Government Models for Emissions Reduction



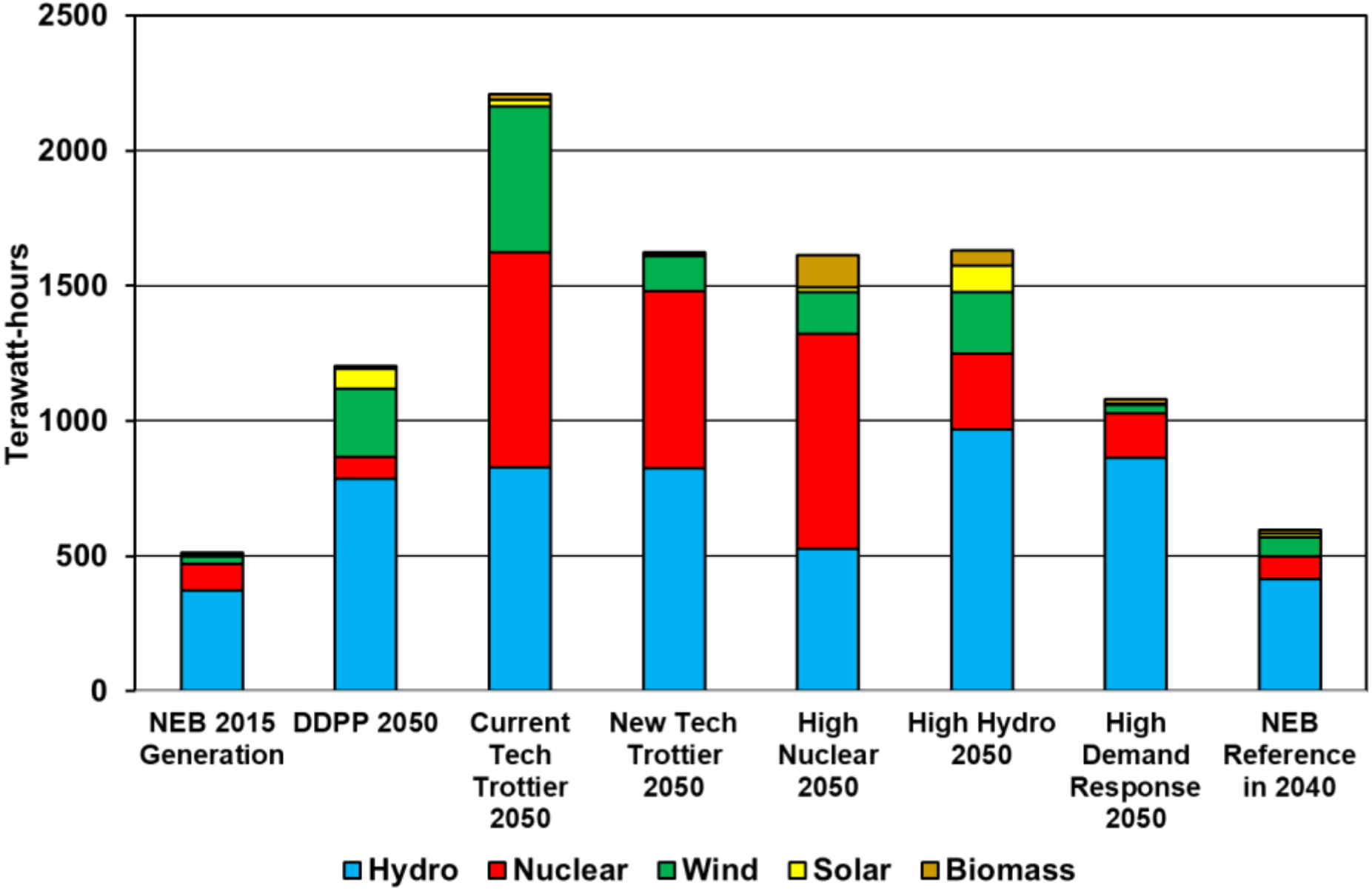
(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Delivered Energy by Source in Government Models for Emissions Reduction



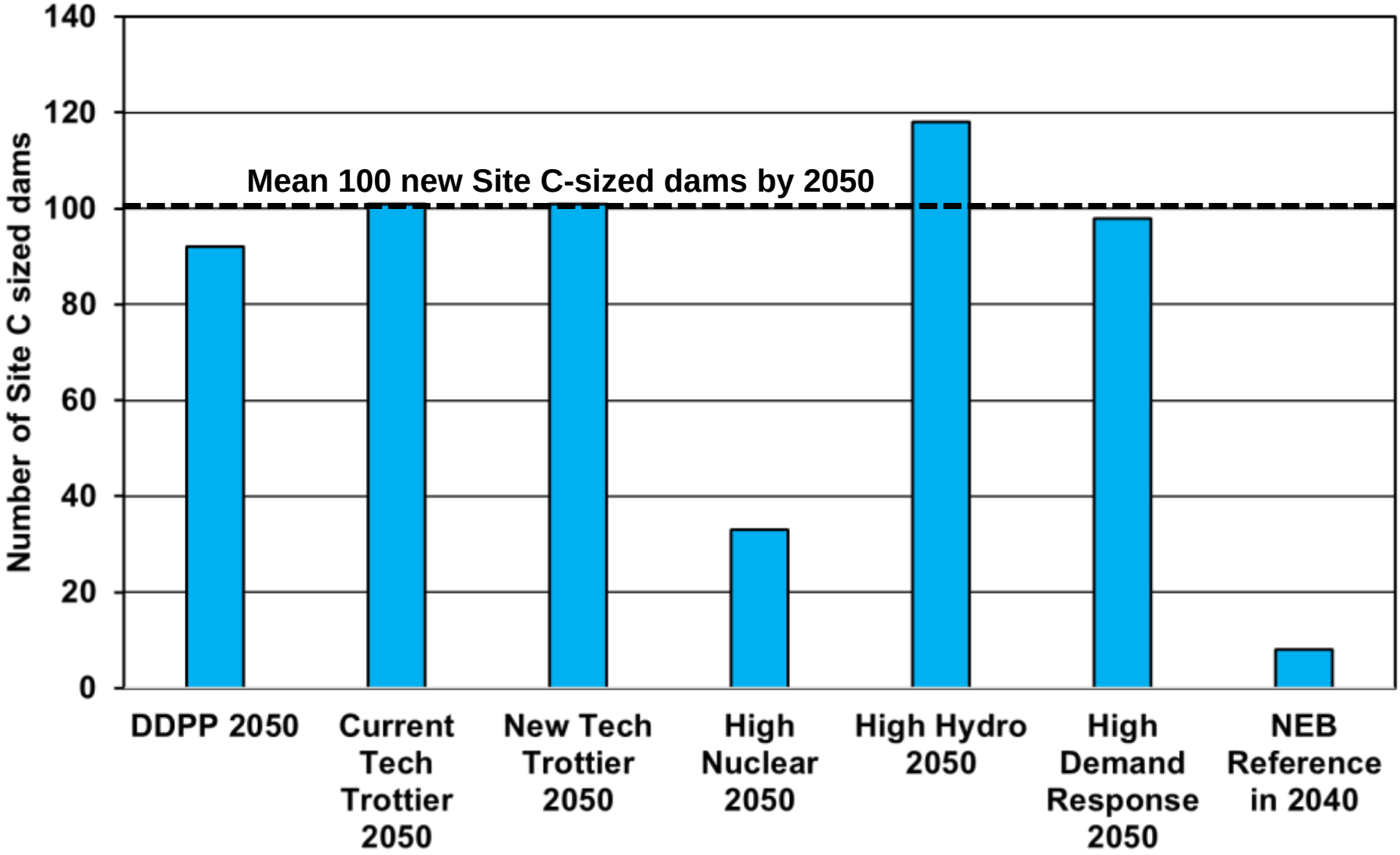
(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Electricity Generation by Source in Government Models for Emissions Reduction



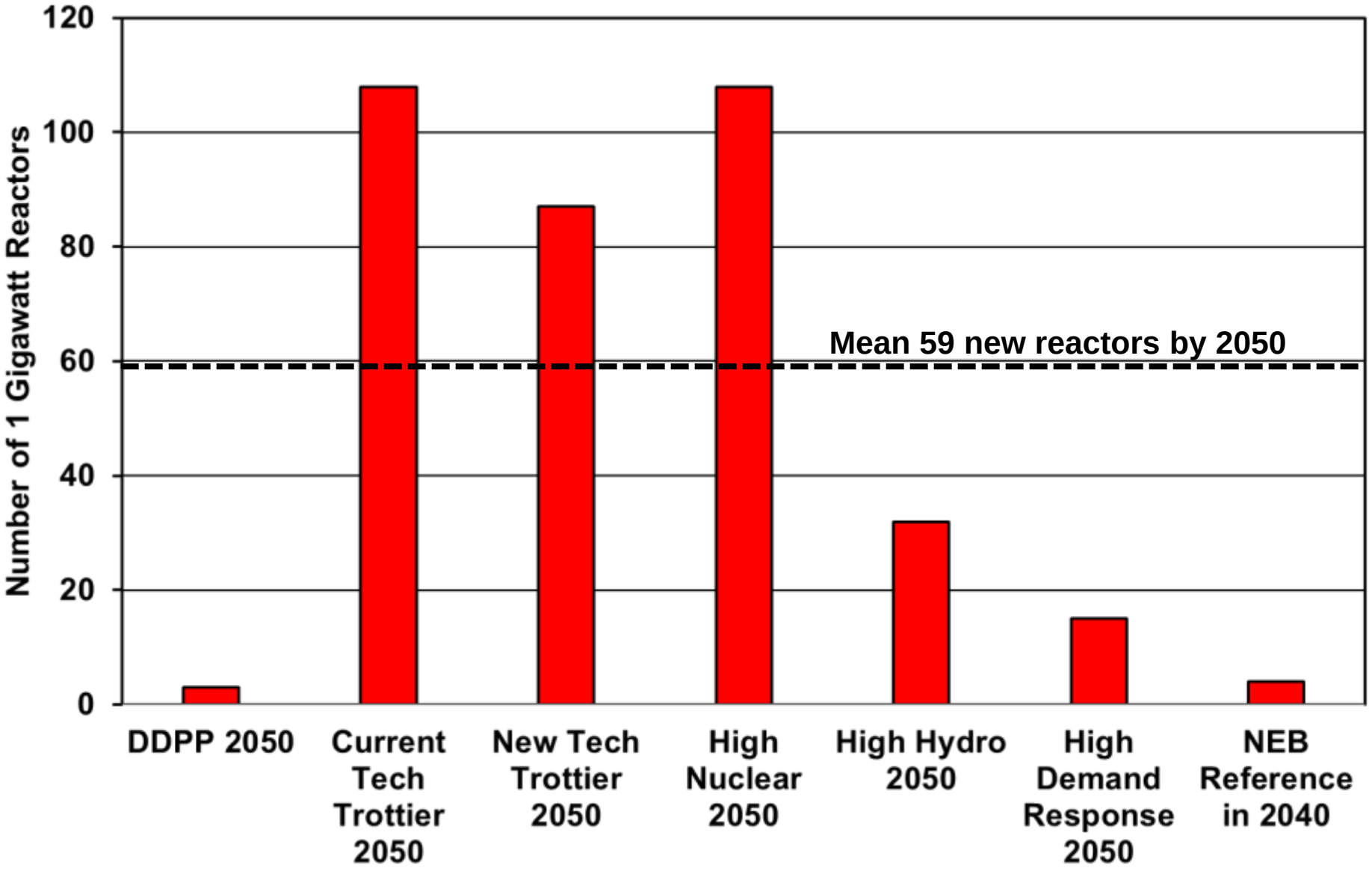
(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Number of New 'Site C-sized' dams required in Government Models for Emissions Reduction



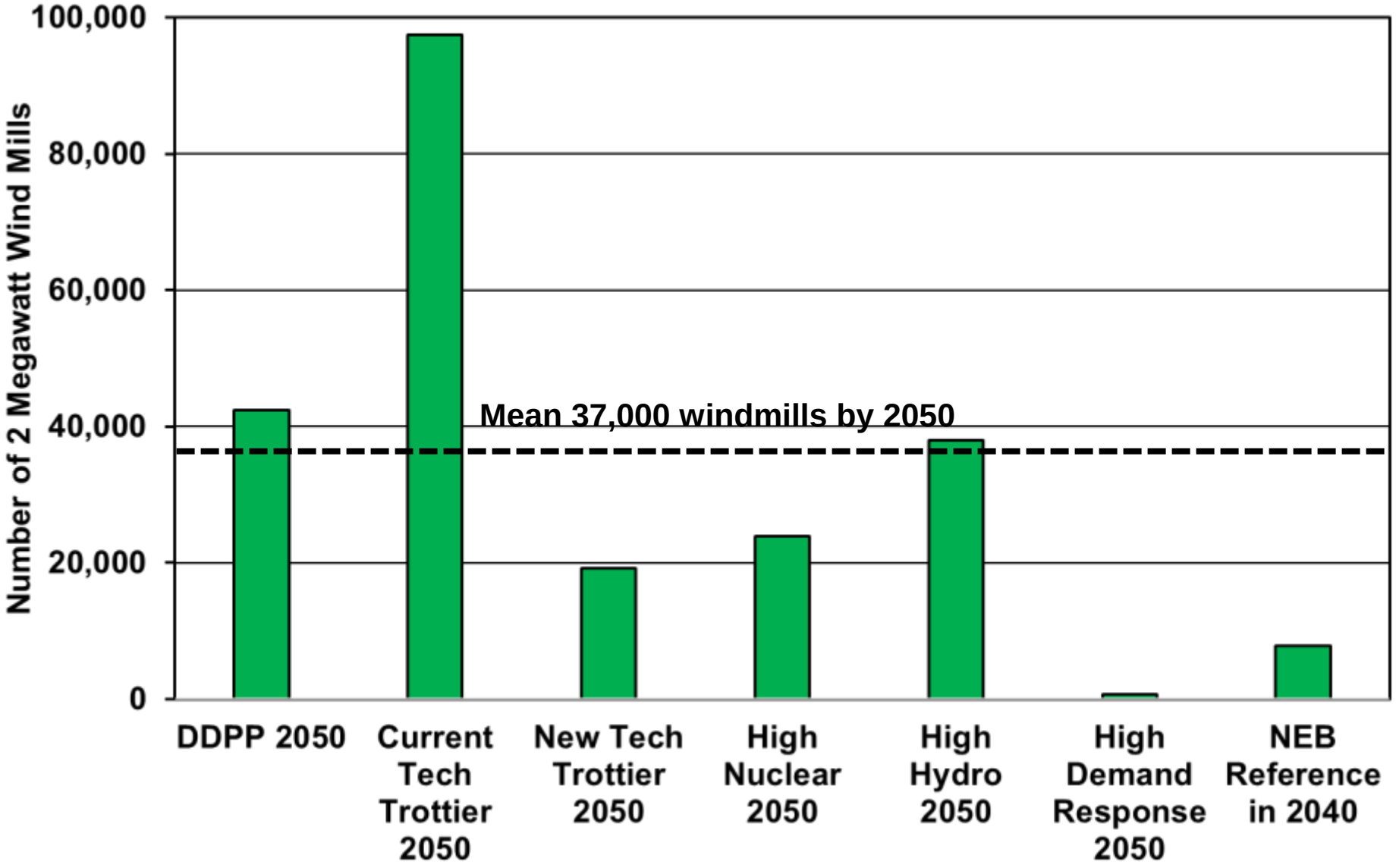
(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Number of New One Gigawatt Reactors required in Government Models for Emissions Reduction



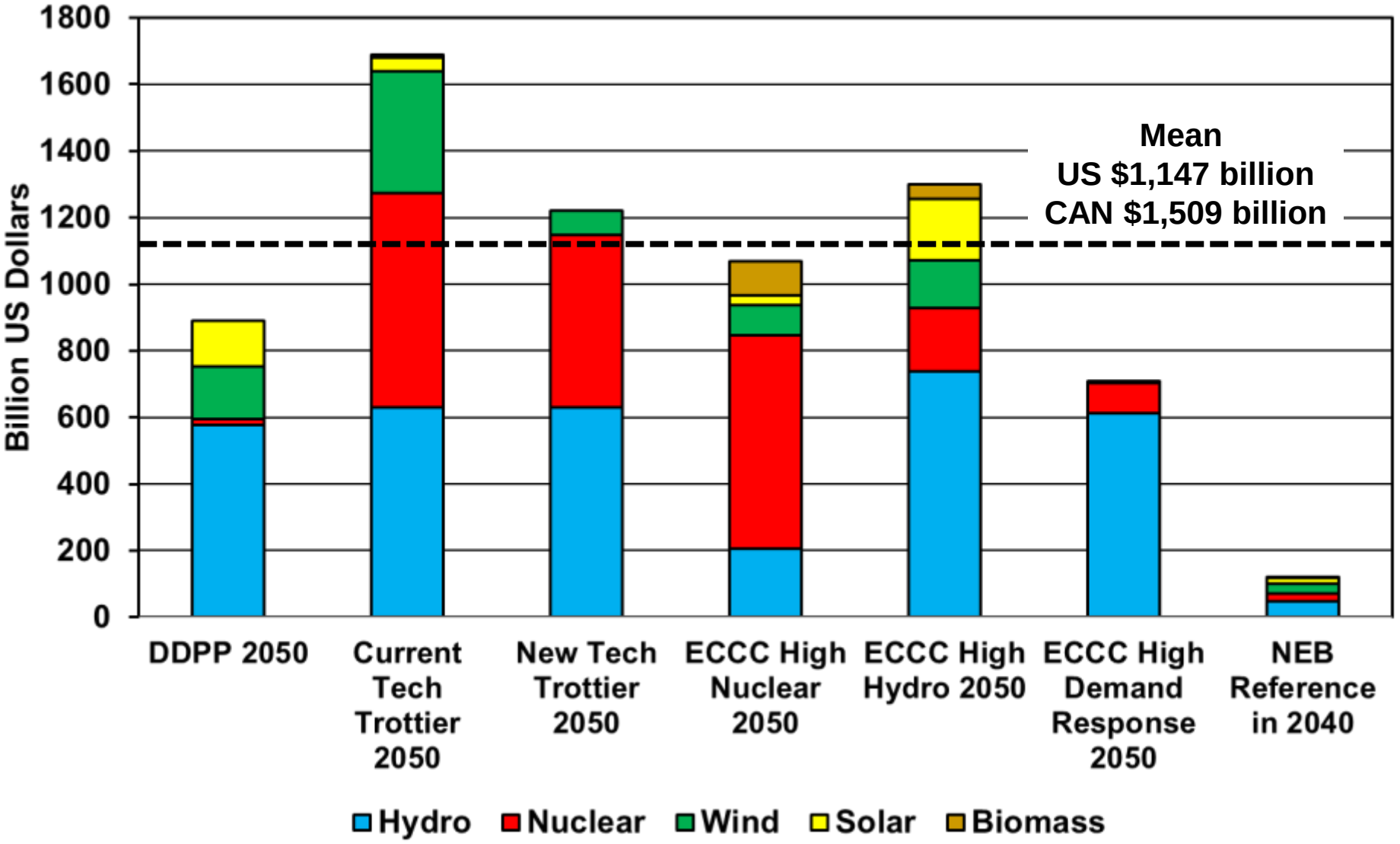
(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Number of 2 Megawatt Wind Mills required in Government Models for Emissions Reduction



(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

Infrastructure Cost for Electricity by Source in Government Models for Emissions Reduction

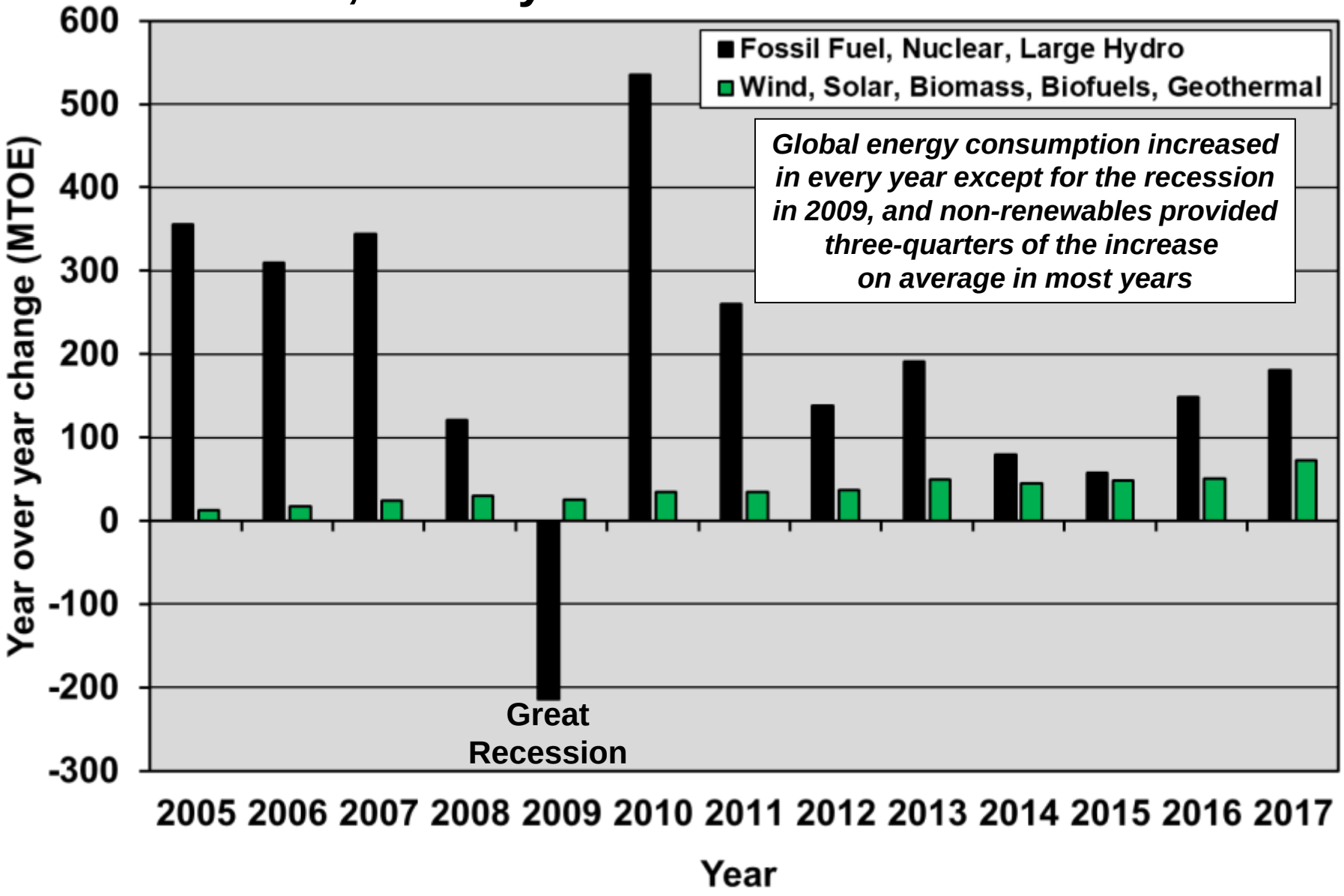


(data from Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy, 2016)

How has the World and Canada done on converting to renewables over the past 15 years?

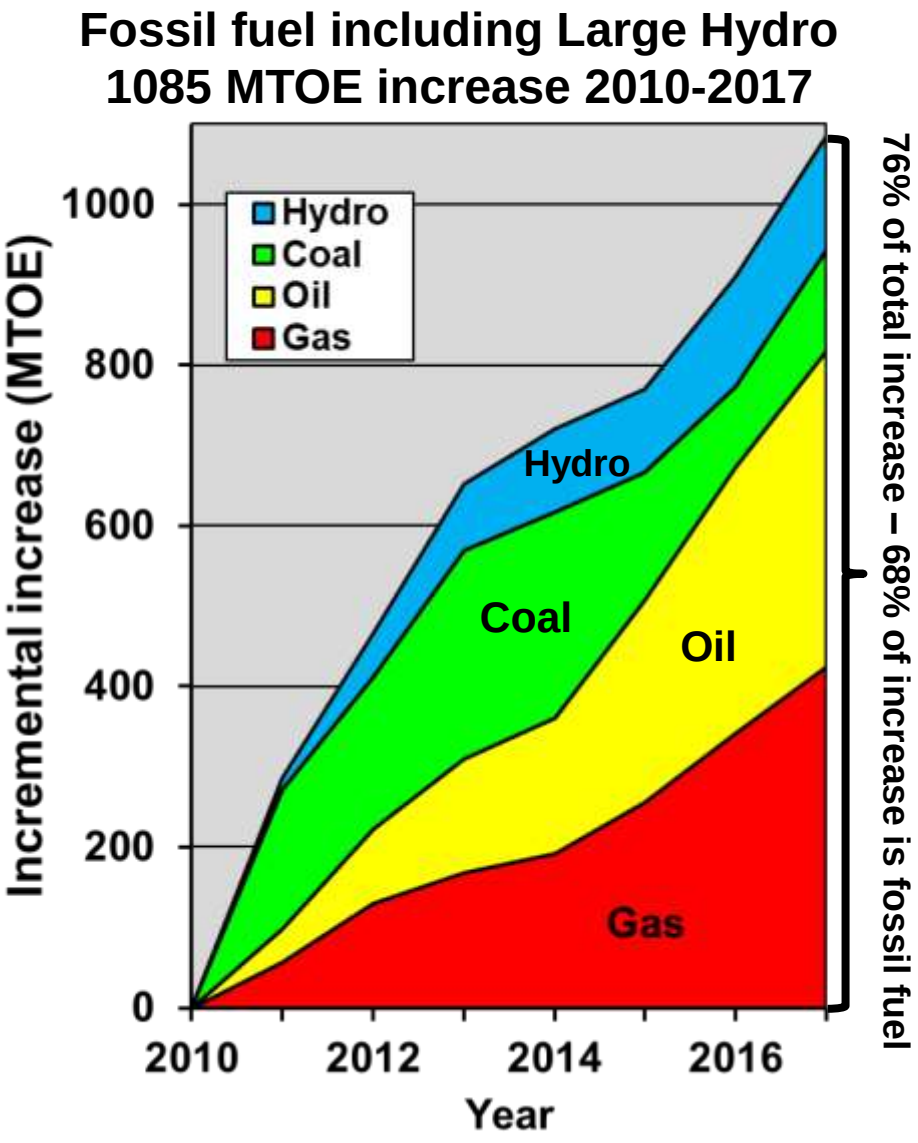
(from here and here)

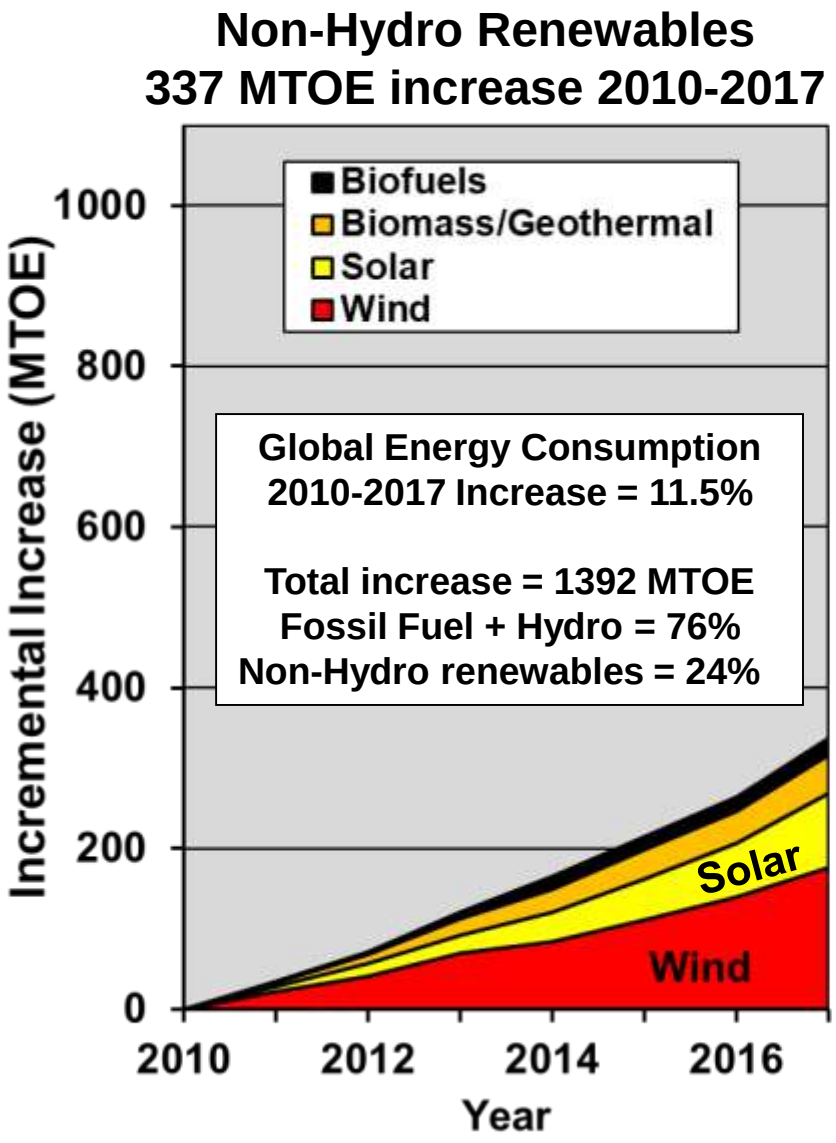
Year-over-year Change in Global Energy Consumption, 2005-2017, Non-hydro renewables versus the rest



(data from BP Statistical Review of World Energy, 2018)

Increase in Global Energy Consumption 2010-2017
Non-Hydro Renewables compared to Fossil Fuel plus Hydro





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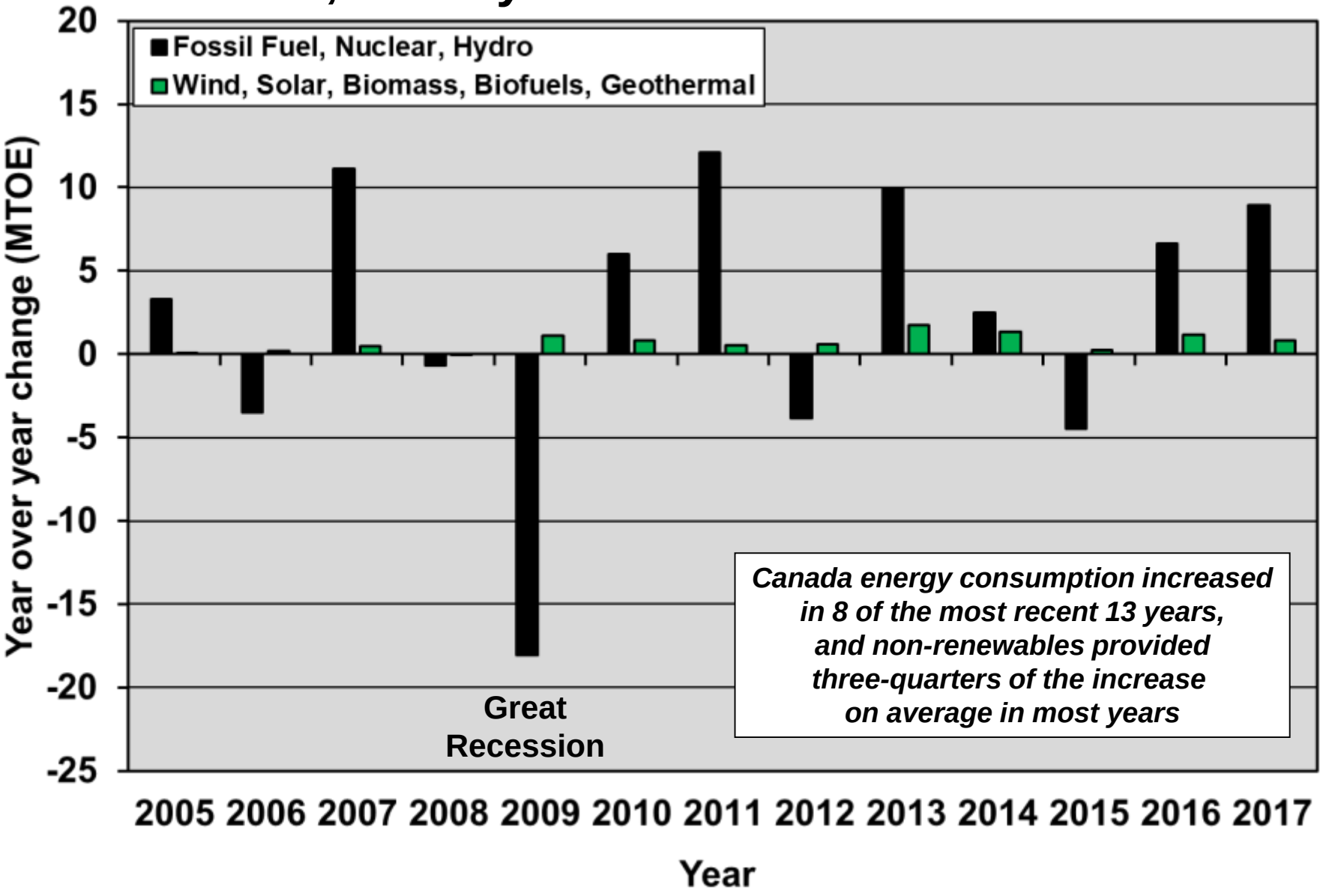

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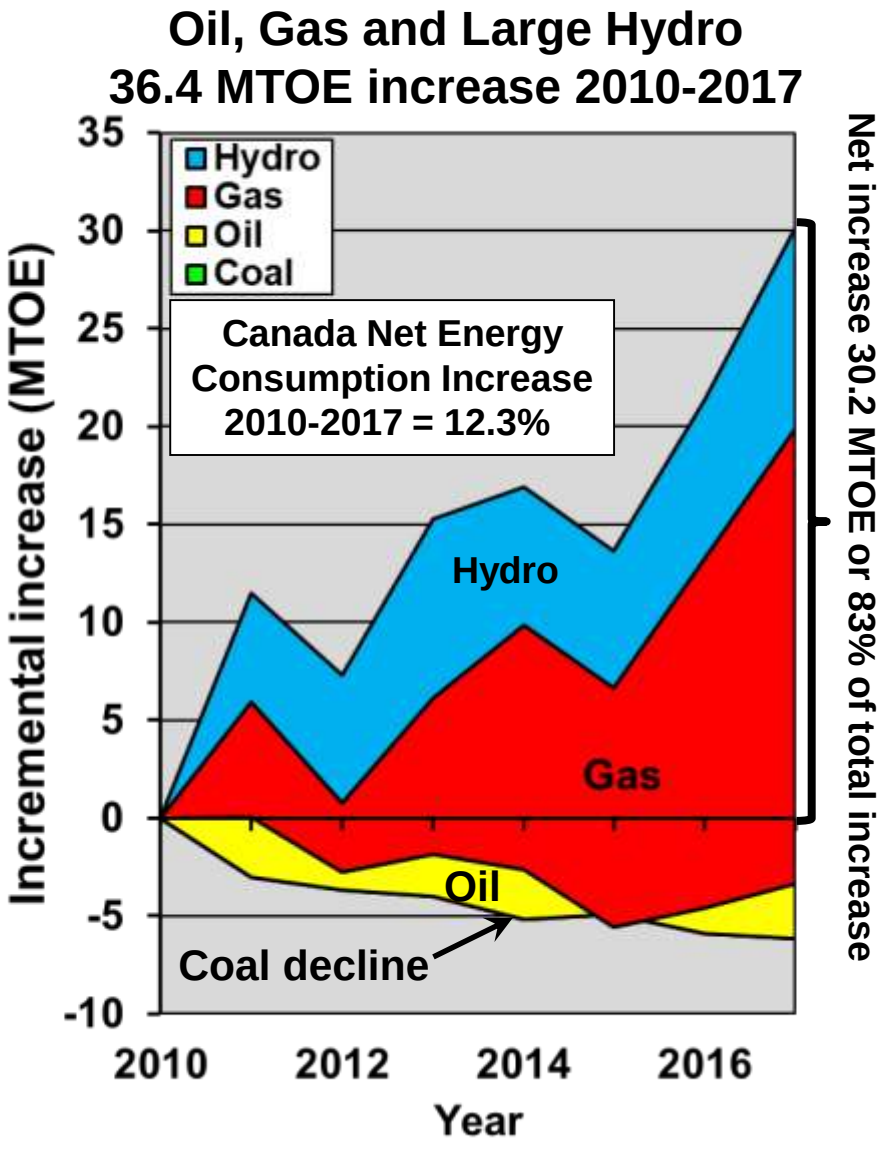
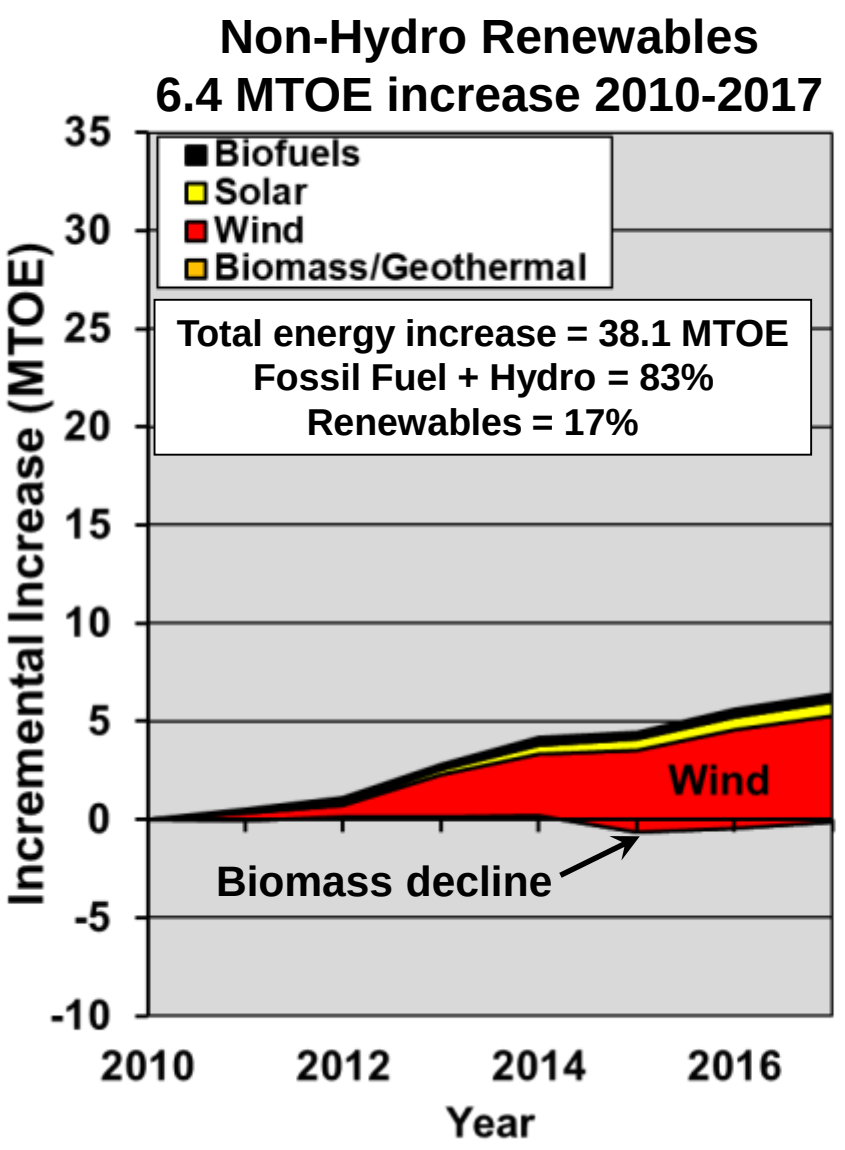




(data from BP Statistical Review of World Energy, 2018)

Implications

- Transitioning to a net-zero carbon world will be very challenging. So far, renewables are only slowing the rate of increase of fossil fuel consumption.

- Canada's current plans are highly unlikely to meet even the Paris Agreement target, let alone longer term emissions reduction goals.

- Proposals to build dozens of new large hydro dams and nuclear reactors are likely non-starters for economic and ecological reasons.

- Oil and gas are therefore likely to be needed at some level for the foreseeable future. But as they are finite resources with serious environmental impacts, selling them off for minimal returns makes no sense.

Implications

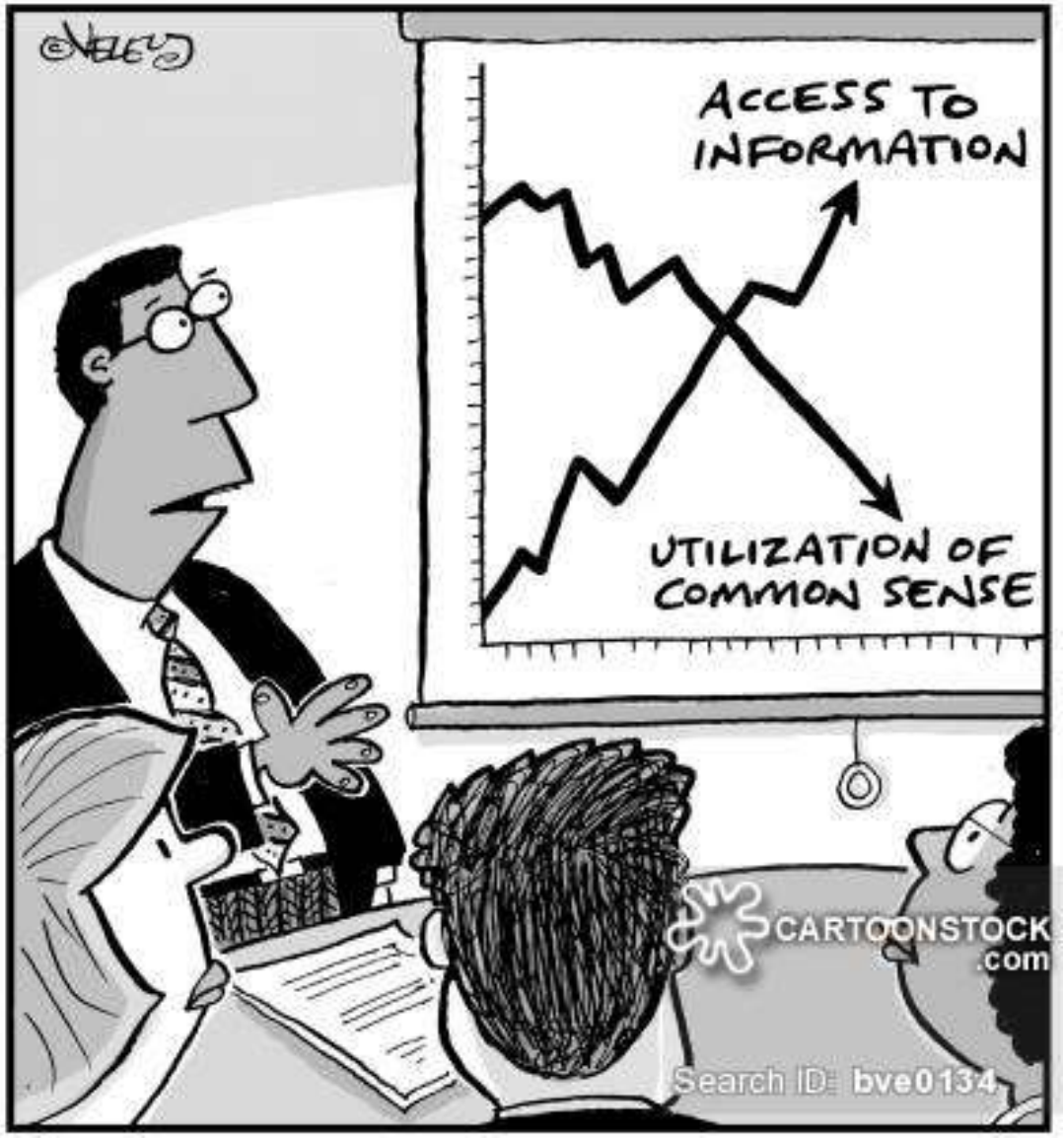
- Pedal-to-the-metal growth in extraction of oil and gas while asserting that this is the way to a carbon-free future would make George Orwell proud.

- REDUCING CONSUMPTION IS KEY.

- This can be expedited with carbon taxes, incentives for retrofits of buildings, net-zero building codes, incentives for renewables, building infrastructure that gives people alternatives to high levels of energy consumption and eliminating fossil fuel subsidies.

- Canada needs an adult conversation about energy to develop a viable strategy that protects both long-term energy security and meets climate commitments. It is a difficult problem that needs facts, not rhetoric, to solve.

Thank You



"Assuming present trends continue, the odds are quite good that we'll become the best-informed extinct species on the planet!"

A few links of many for more information

Canada's energy outlook main report (May 2018)

Parkland Institute – policy and energy

Canadian Centre for Policy Alternatives – policy and energy

Post Carbon Institute – energy, sustainability and resilience

Resilience – energy, sustainability and resilience

Low Tech Magazine – low tech solutions

Living Energy Farm – People living a viable low energy life