B.C. LNG and the "Shale Revolution"

Myths and Realities

J. David Hughes

Global Sustainability Research Inc.

Points to be covered:

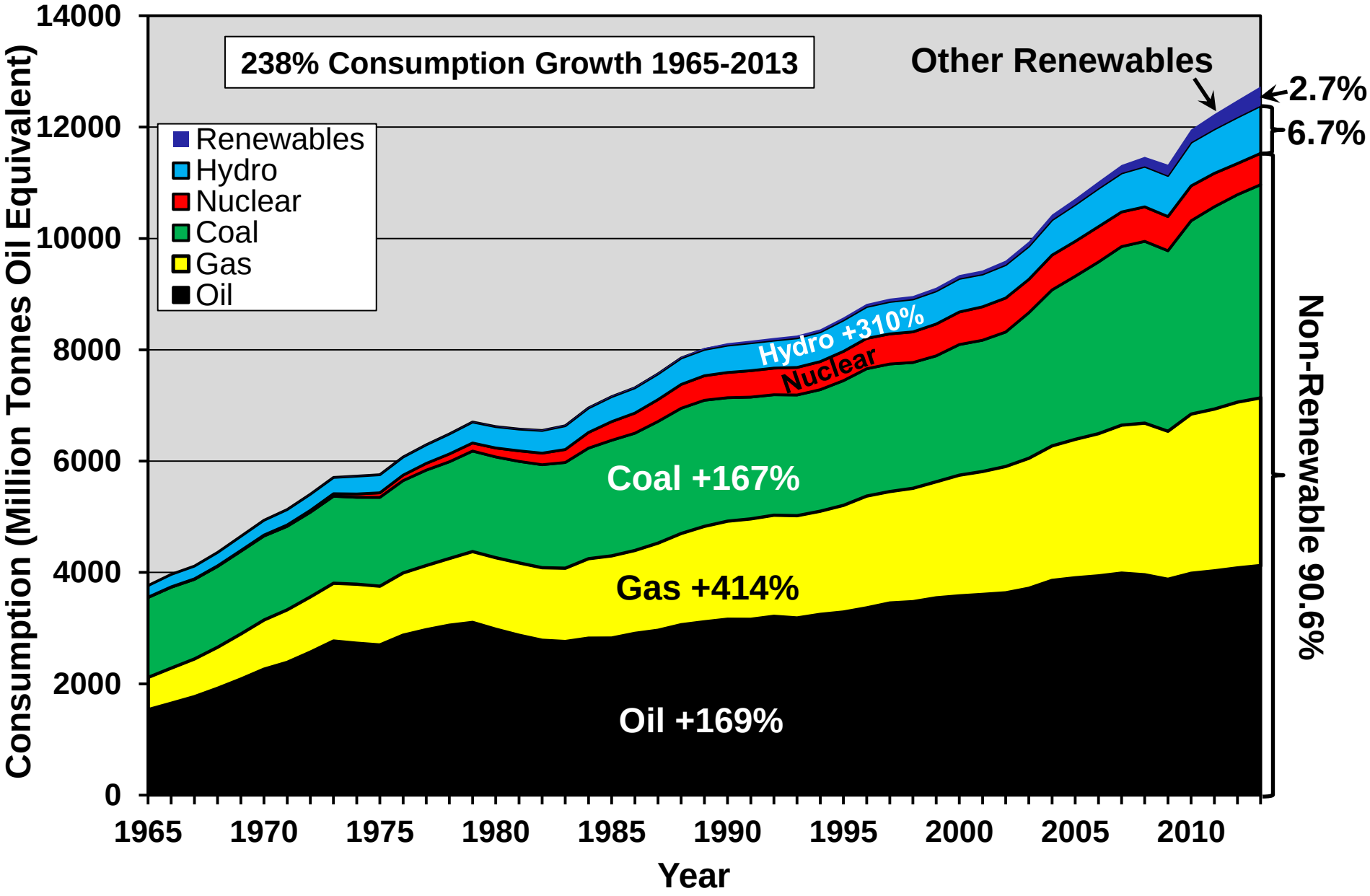
- *Some Global Context - The ENERGY SUSTAINABILITY DILEMMA*

-*The SHALE REVOLUTION and CONVENTIONAL WISDOM - a look at the fundamentals with examples from major U.S. Plays*

- *Canadian gas supply forecasts and BC LNG – drilling requirements, environmental impacts and Canadian energy security*

- IMPLICATIONS for long term energy sustainability

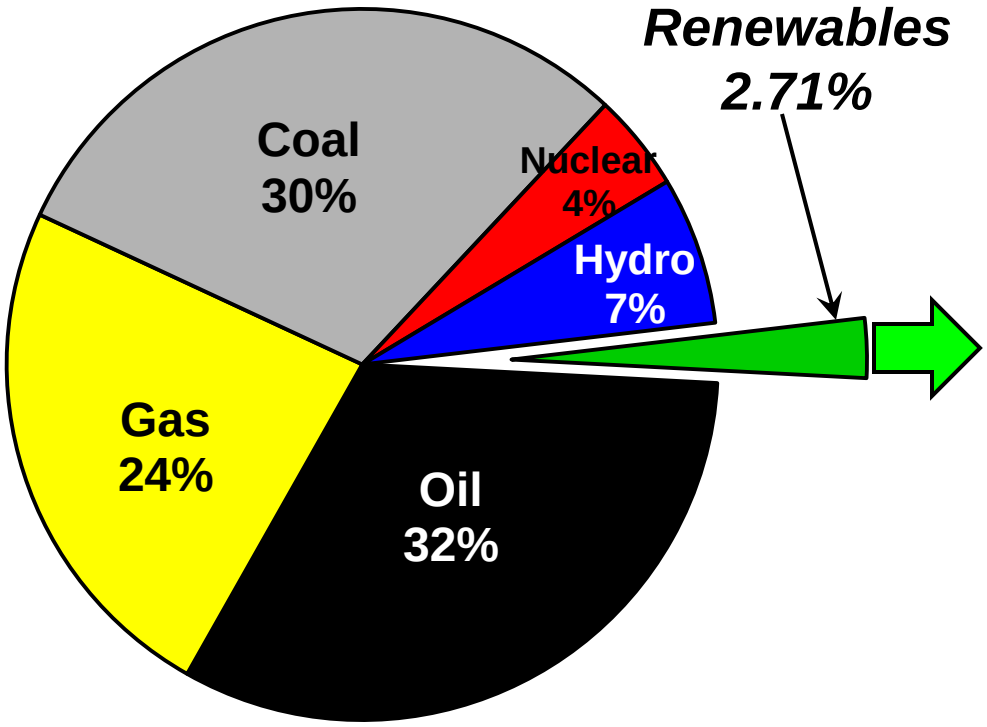
World Consumption of Primary Energy by Fuel, 1965-2013



(BP Statistical Review, 2014; other renewables include wind, solar, biomass, geothermal and biofuels)

Global Primary Energy Consumption by Source in 2013
A Comparison to Total Non-Hydro Renewable* Energy

Total Energy by Source
12730 MTOE

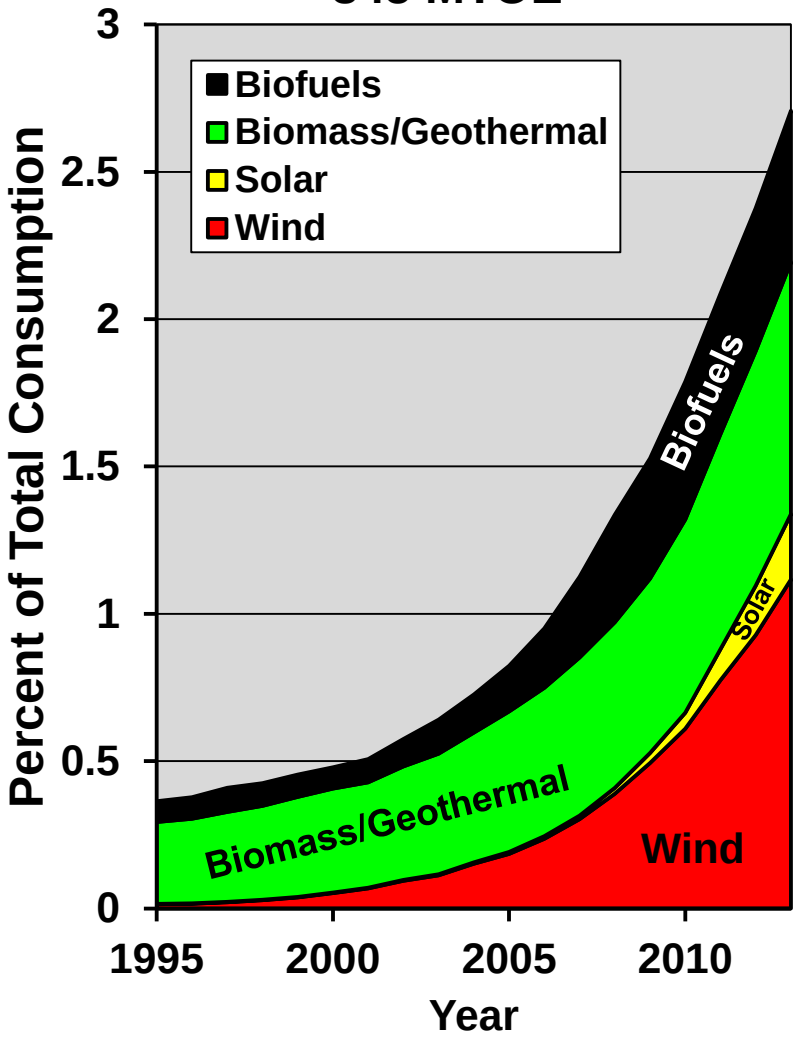


Large Hydro plus Renewables = 9.4%

Total consumption has increased by 42% more than all 2013 renewables since 2011

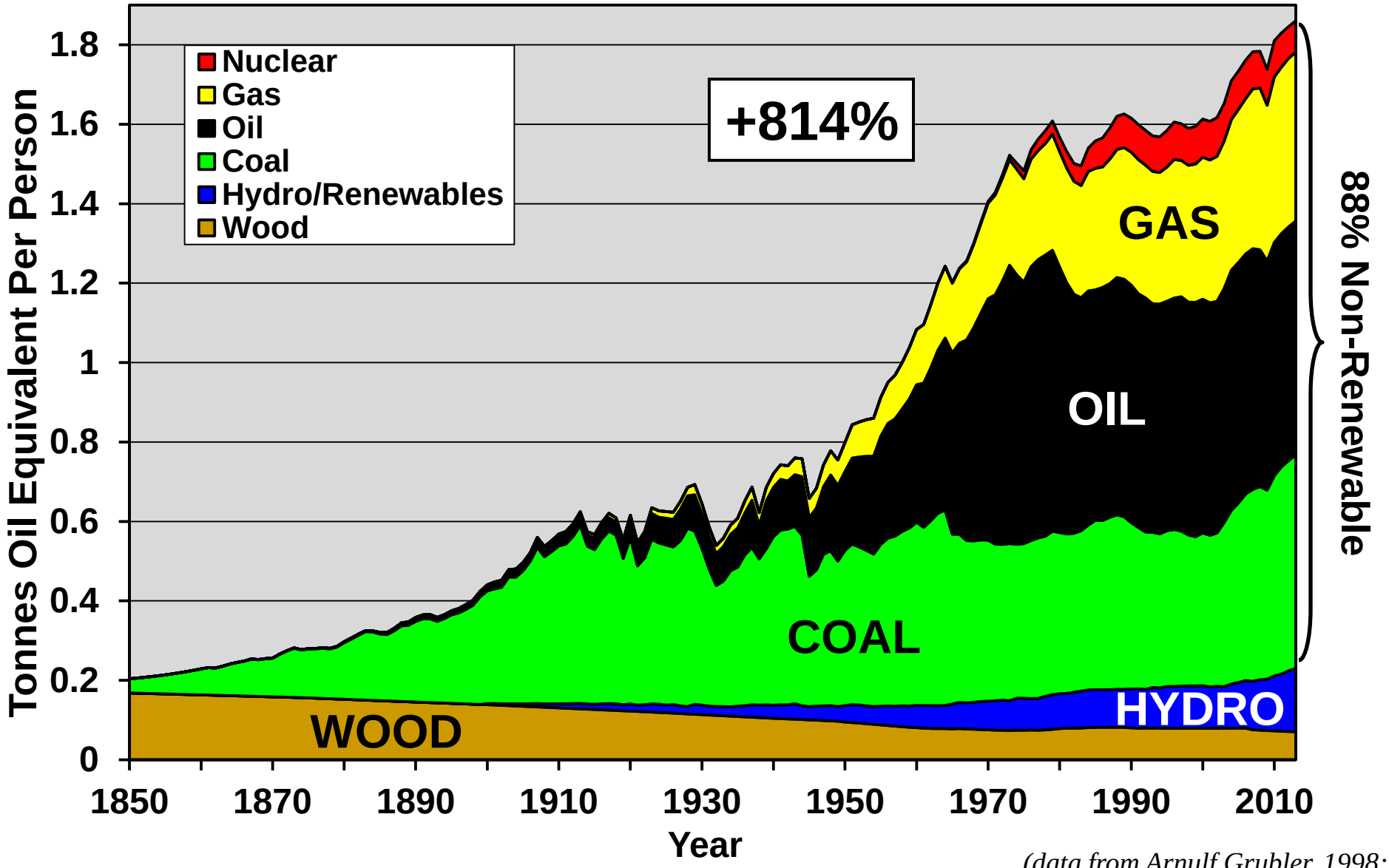
***excluding traditional biomass estimated at 9% (IRENA)**

Renewable Energy by Source
345 MTOE



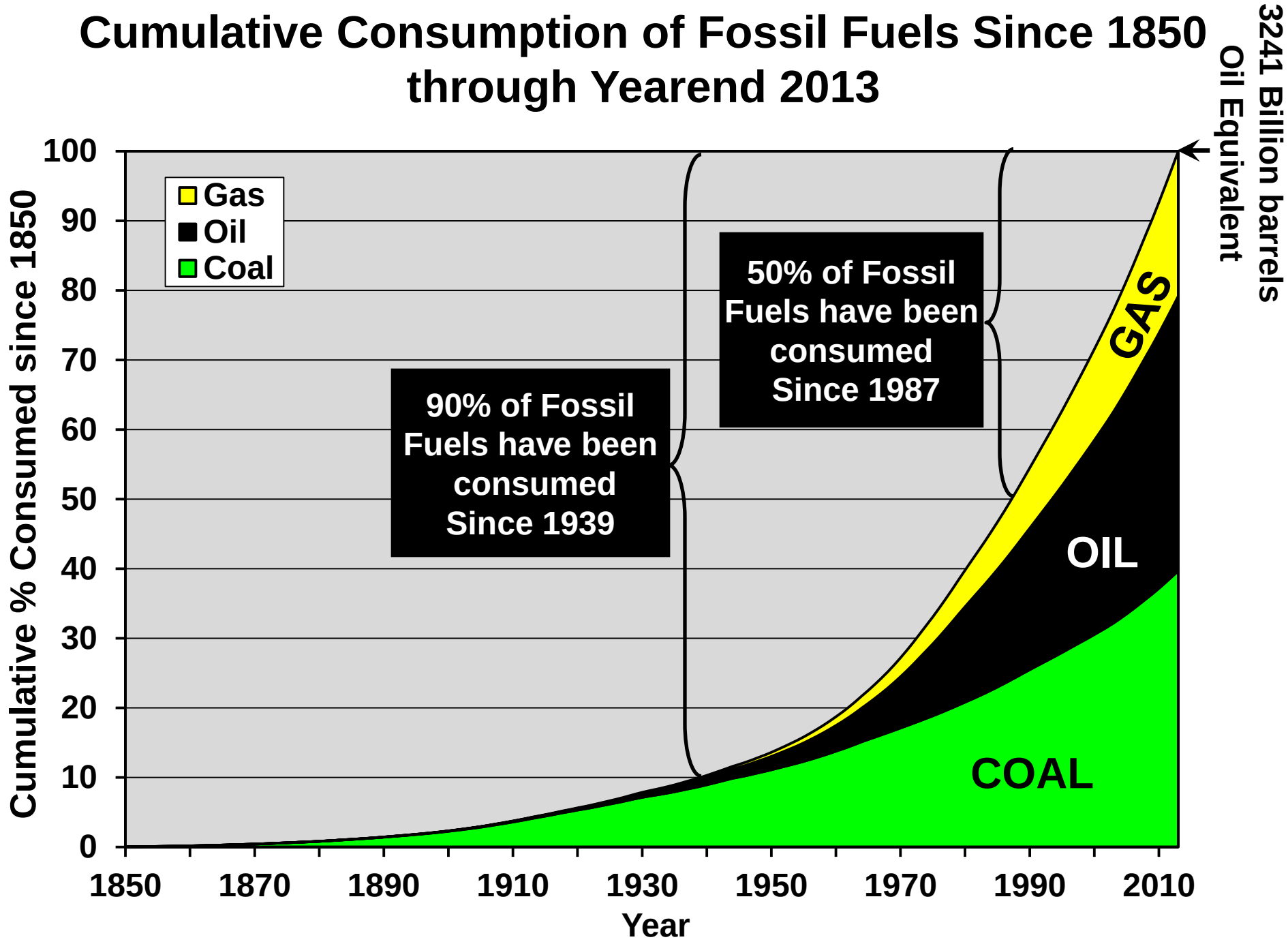
(data from BP Statistical Review of World Energy, 2014)

World Per Capita Annual Primary Energy Consumption by Fuel 1850-2013



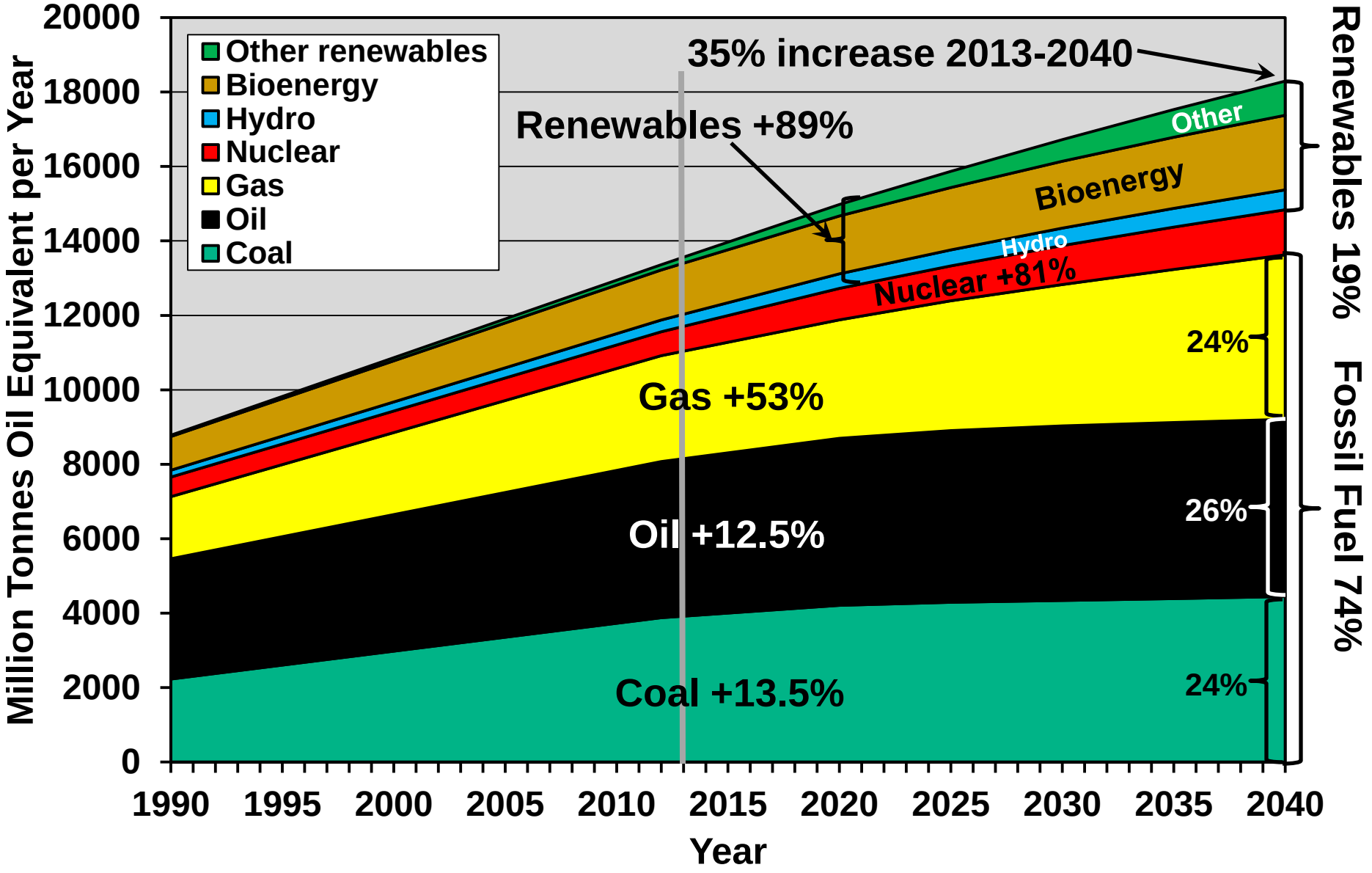
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2014; EIA, 2014)

Cumulative Consumption of Fossil Fuels Since 1850 through Yearend 2013



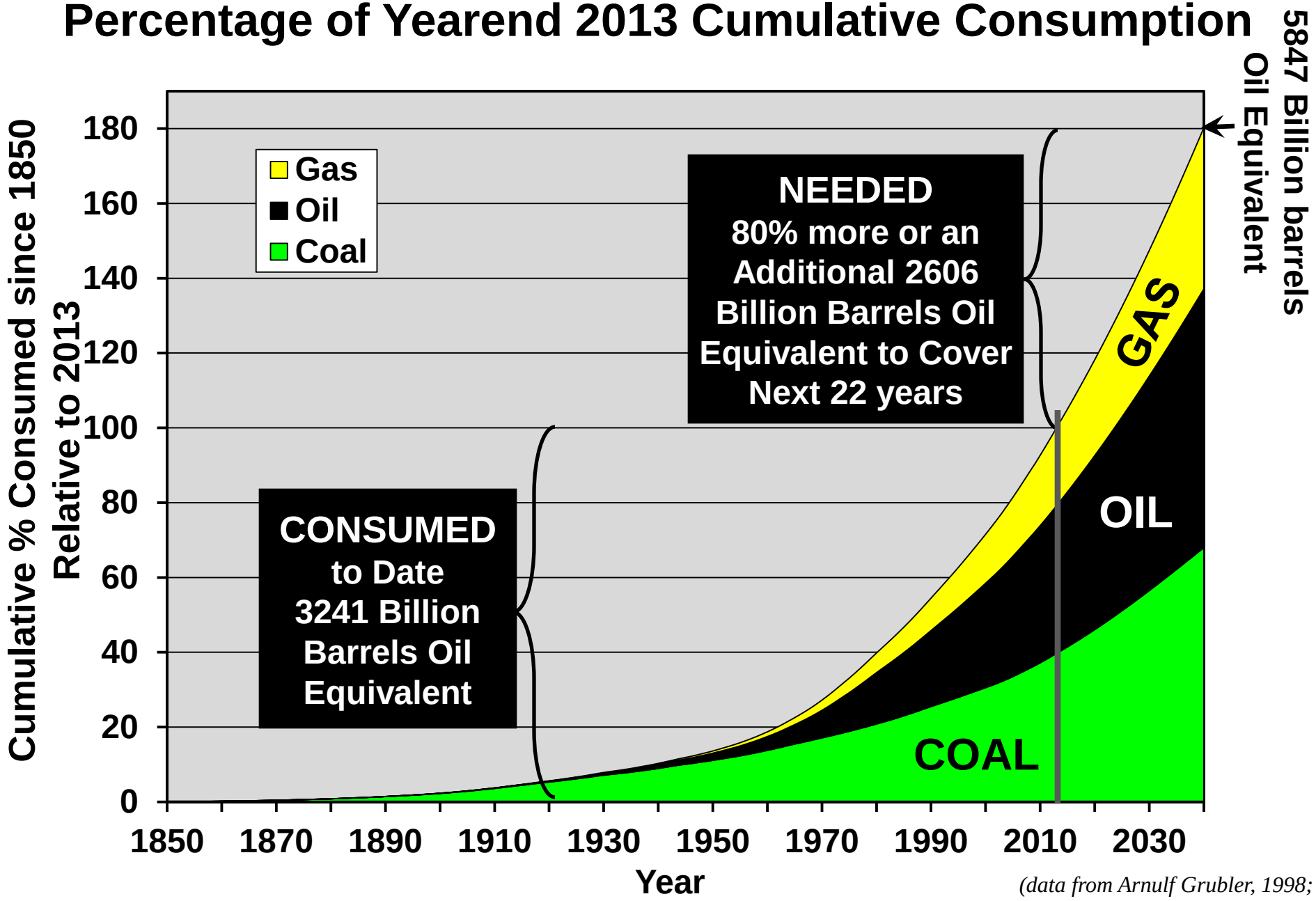
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2014)

World Energy Consumption by Source, 1990-2040
IEA World Energy Outlook 2014 New Policies Scenario



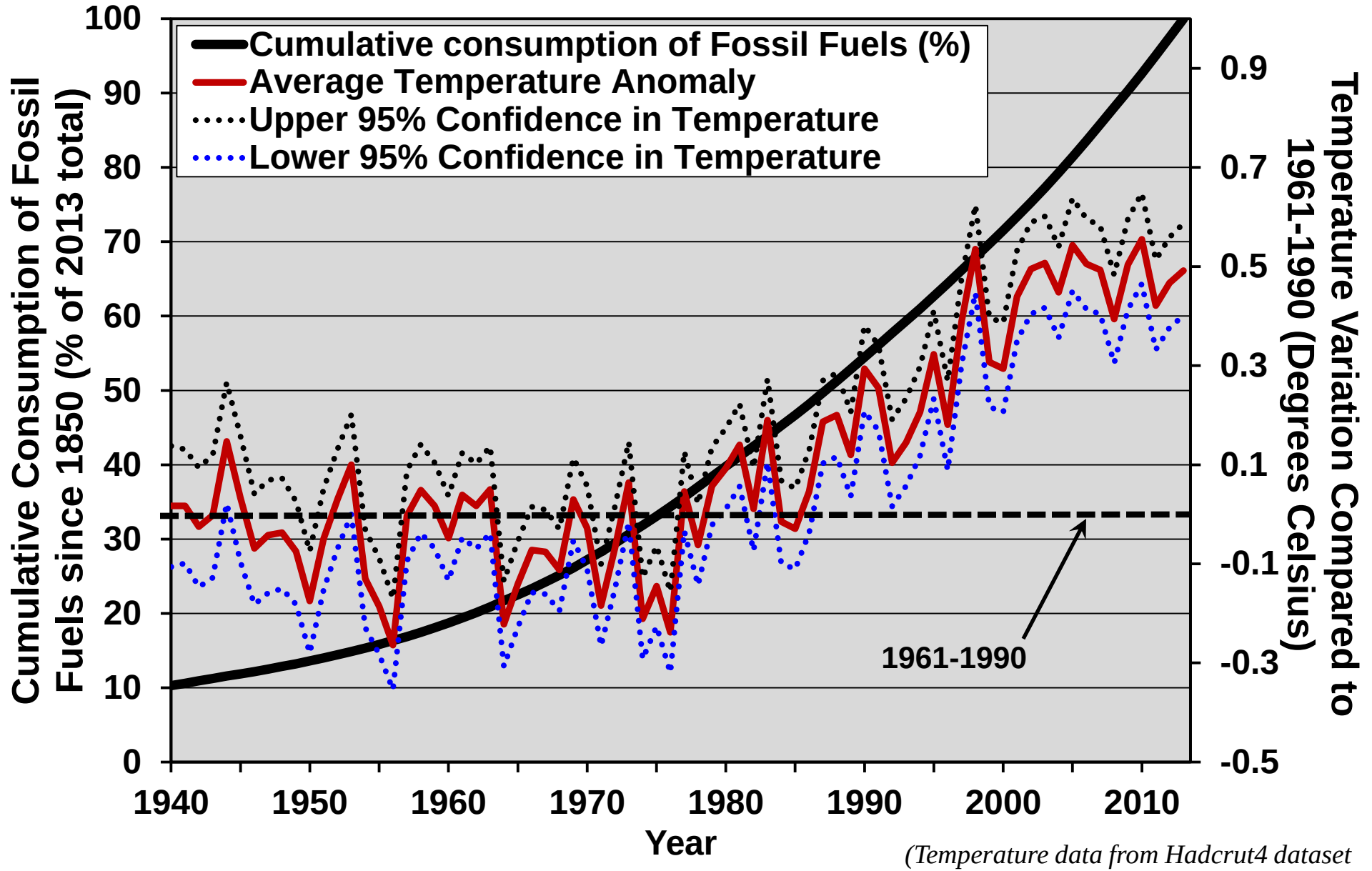
(data from IEA World Energy Outlook, 2014, New Policy Scenario; % increase is from 2013-2040)

Projected Consumption of Fossil Fuels Through 2040 as a Percentage of Yearend 2013 Cumulative Consumption



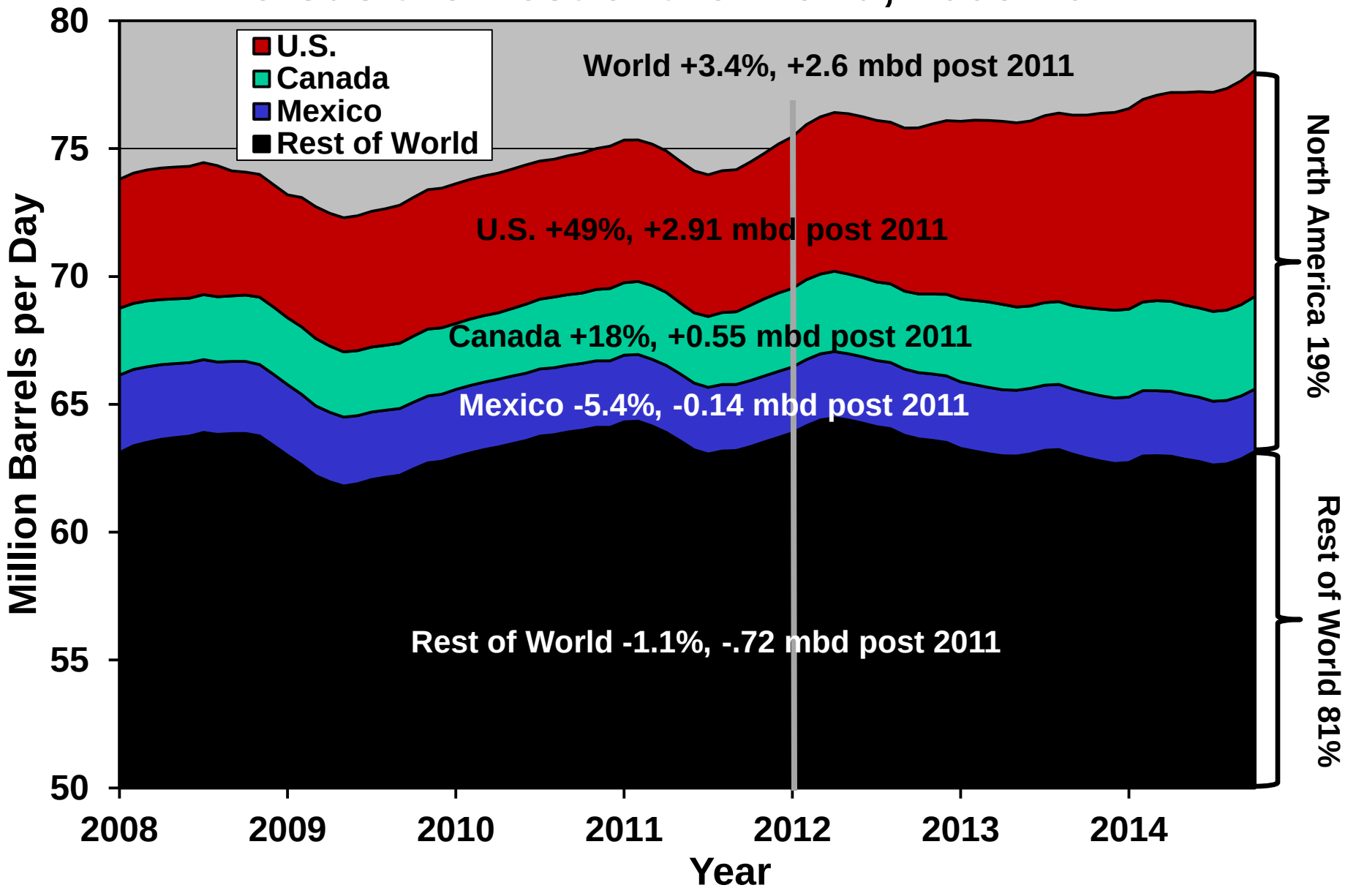
(data from Arnulf Grubler, 1998; BP Statistical Review of World Energy, 2014; EIA IEO 2013Reference case projection)

Cumulative Consumption of Fossil Fuels versus Annual Global Temperature, 1940-2013



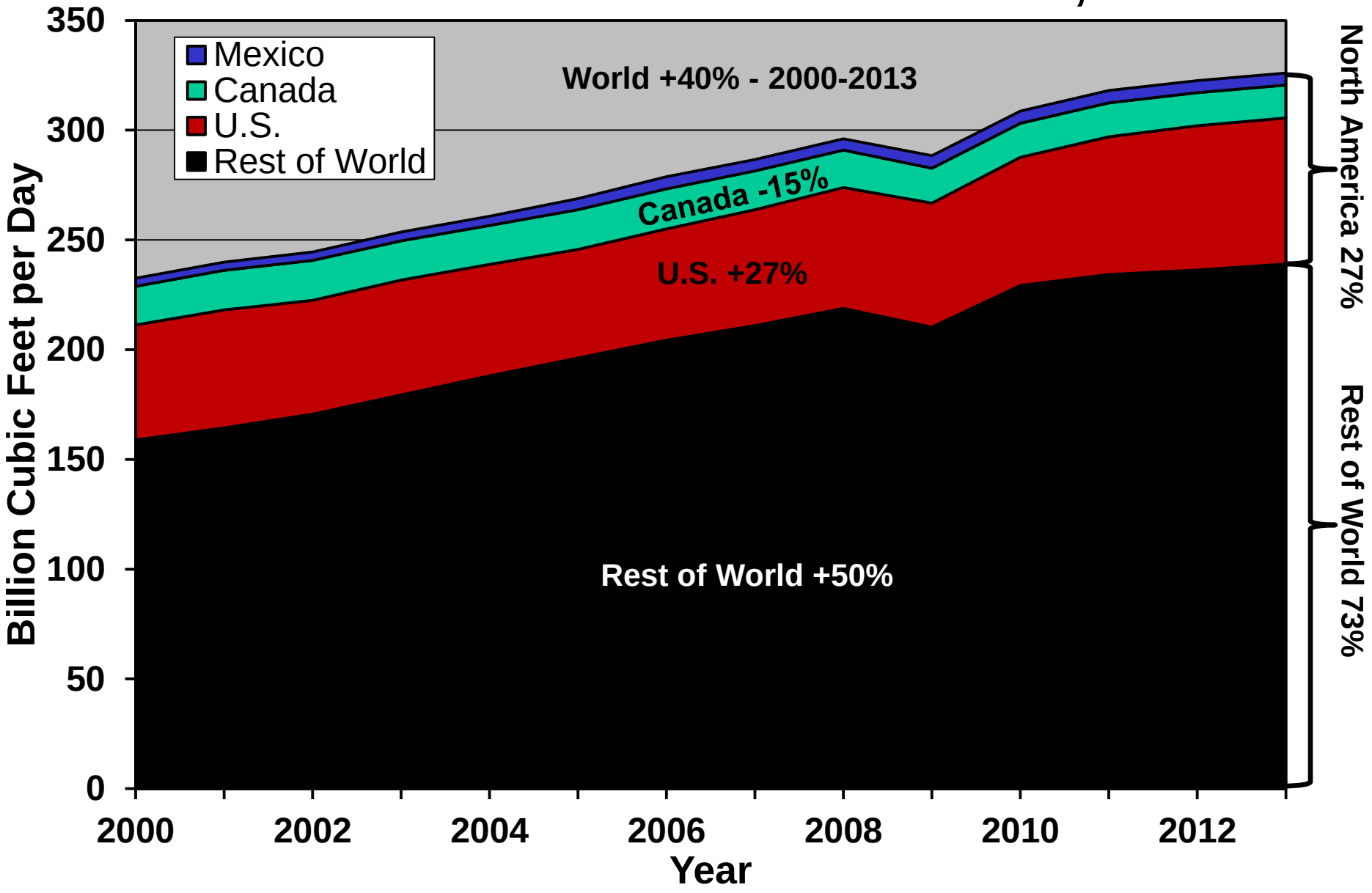
(Temperature data from Hadcrut4 dataset retrieved November 2014; fossil fuel consumption from BP , 2014, and Arnulf Grubler, 1998)

Crude Oil plus Condensate Production – North America versus the Rest of the World, 2008-2014



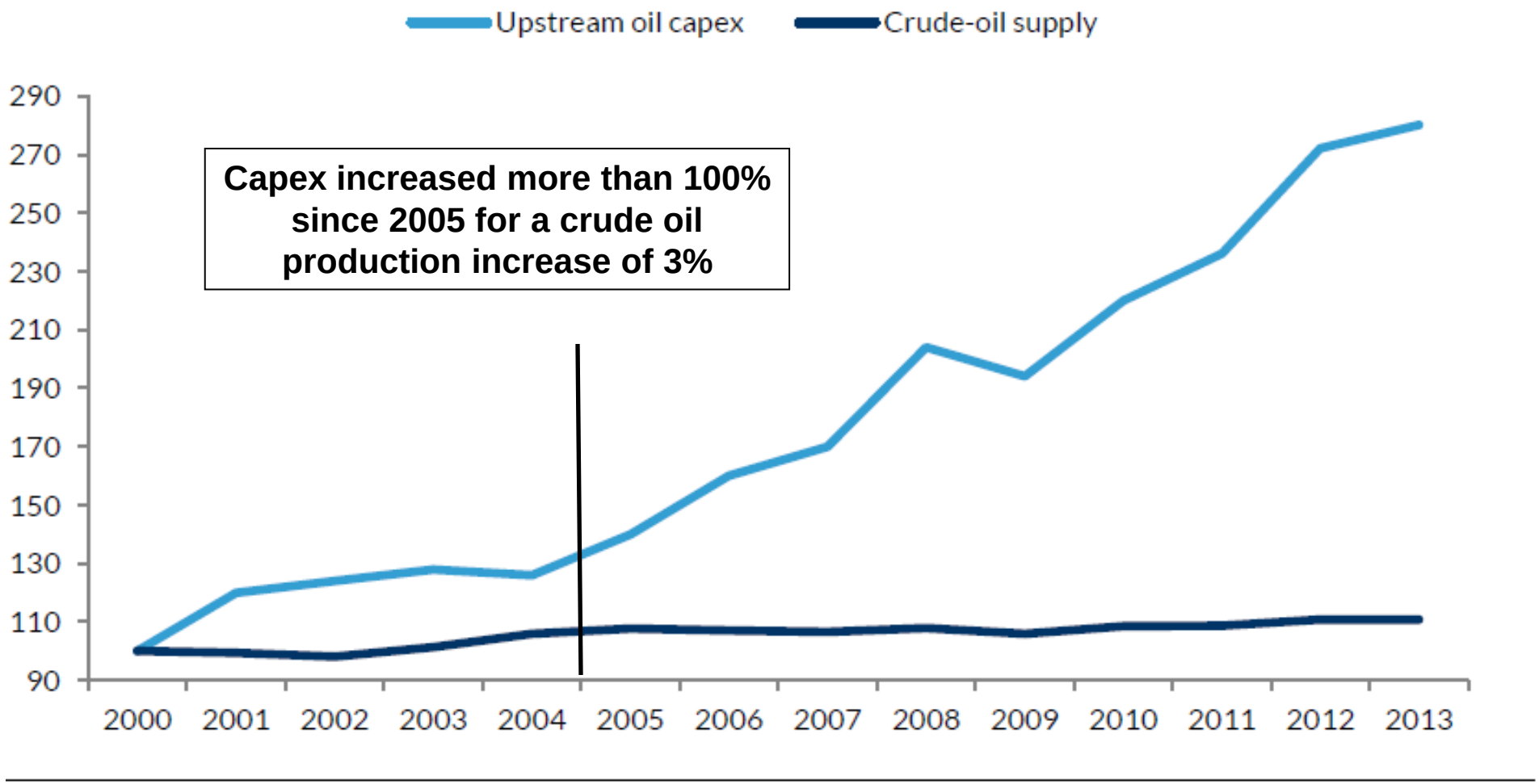
(data from EIA International Energy Statistics retrieved April 2015, 5-month moving average)

Natural Gas Production
North America versus the Rest of the World, 2000-2013



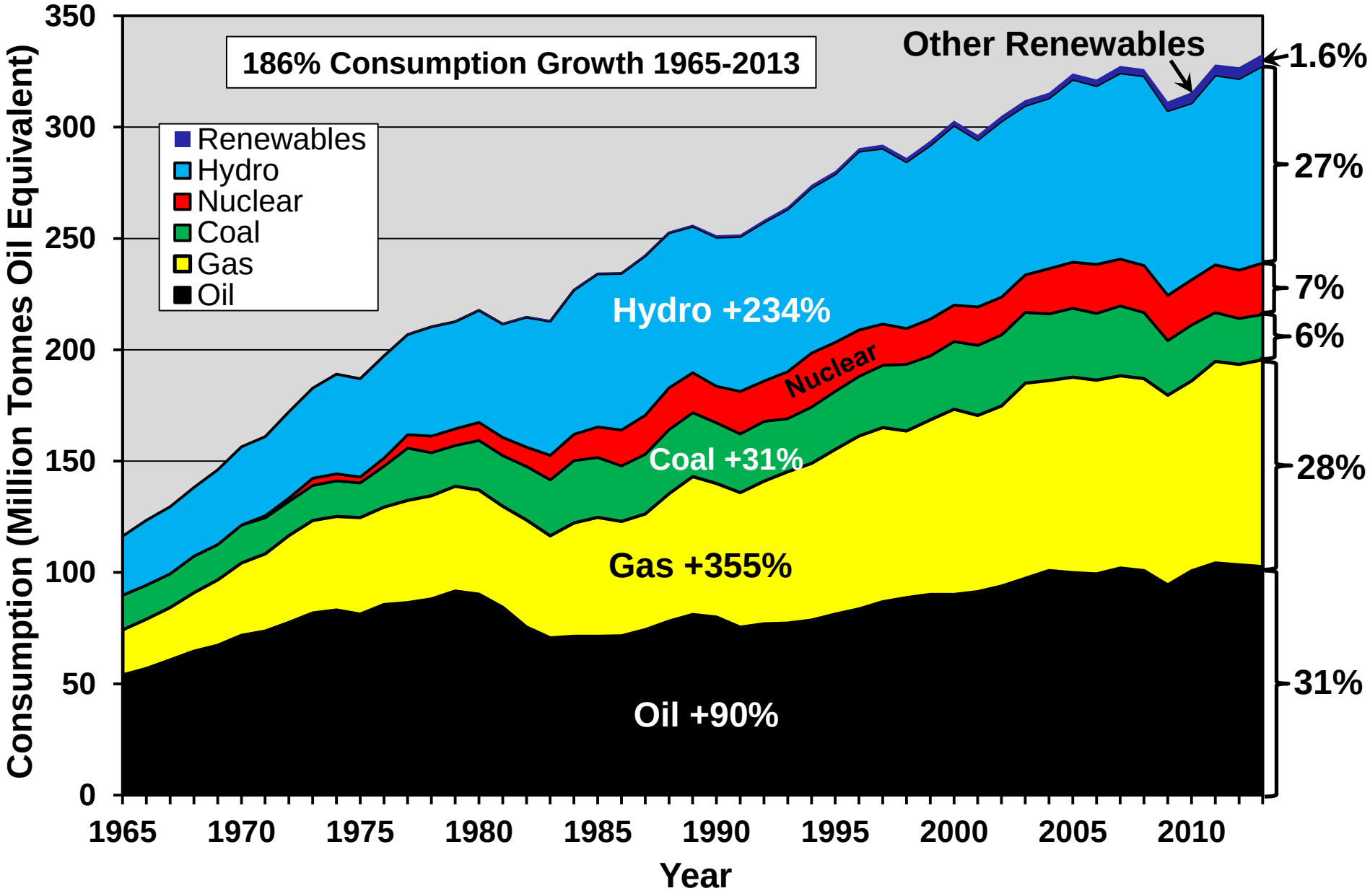
(data from BP Statistical Review, 2014)

Change in Upstream Oil Capex and Oil Supply since 2000, with 2000 Indexed to 100



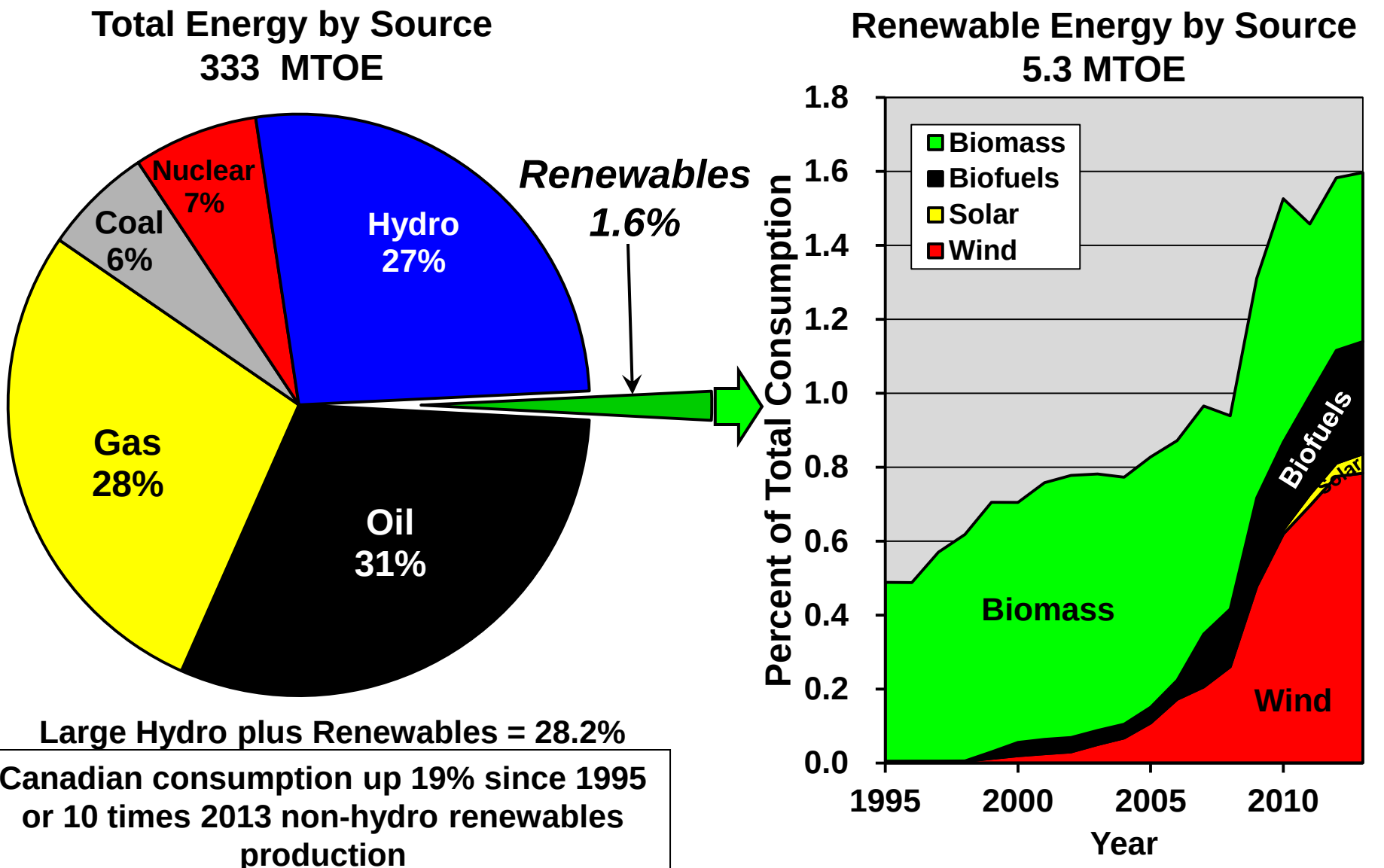
Source: Kepler Cheuvreux based on EIA and IEA data

Canadian Consumption of Primary Energy by Fuel, 1965-2013



(BP Statistical Review, 2014; other renewables include wind, solar, biomass, geothermal and biofuels)

Canada Primary Energy Consumption by Source in 2013
A Comparison to Total Non-Hydro Renewable Energy

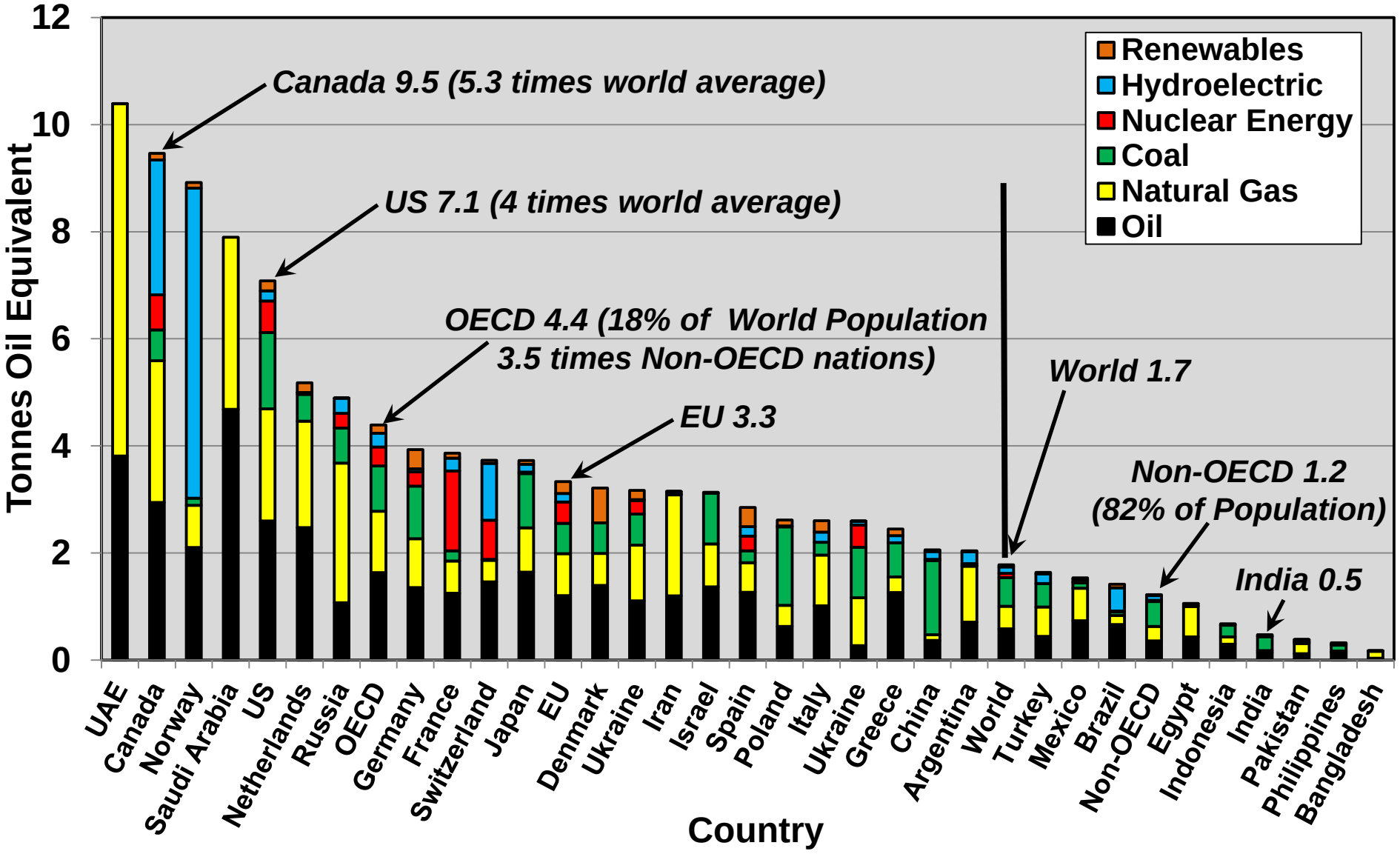


Large Hydro plus Renewables = 28.2%

Canadian consumption up 19% since 1995 or 10 times 2013 non-hydro renewables production

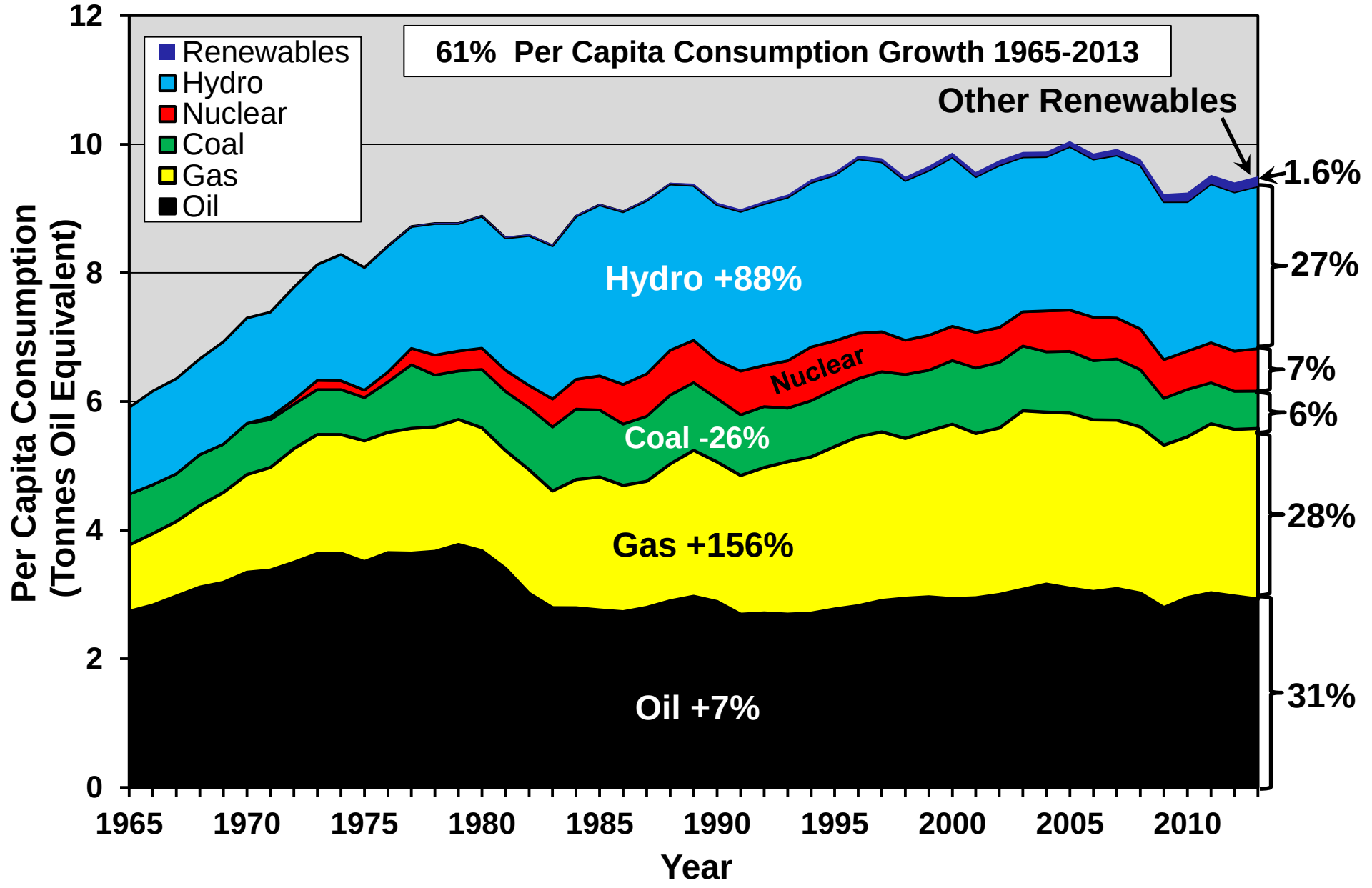
(data from BP Statistical Review of World Energy, 2014)

Per Capita Consumption of Primary Energy by Fuel and Country in 2013



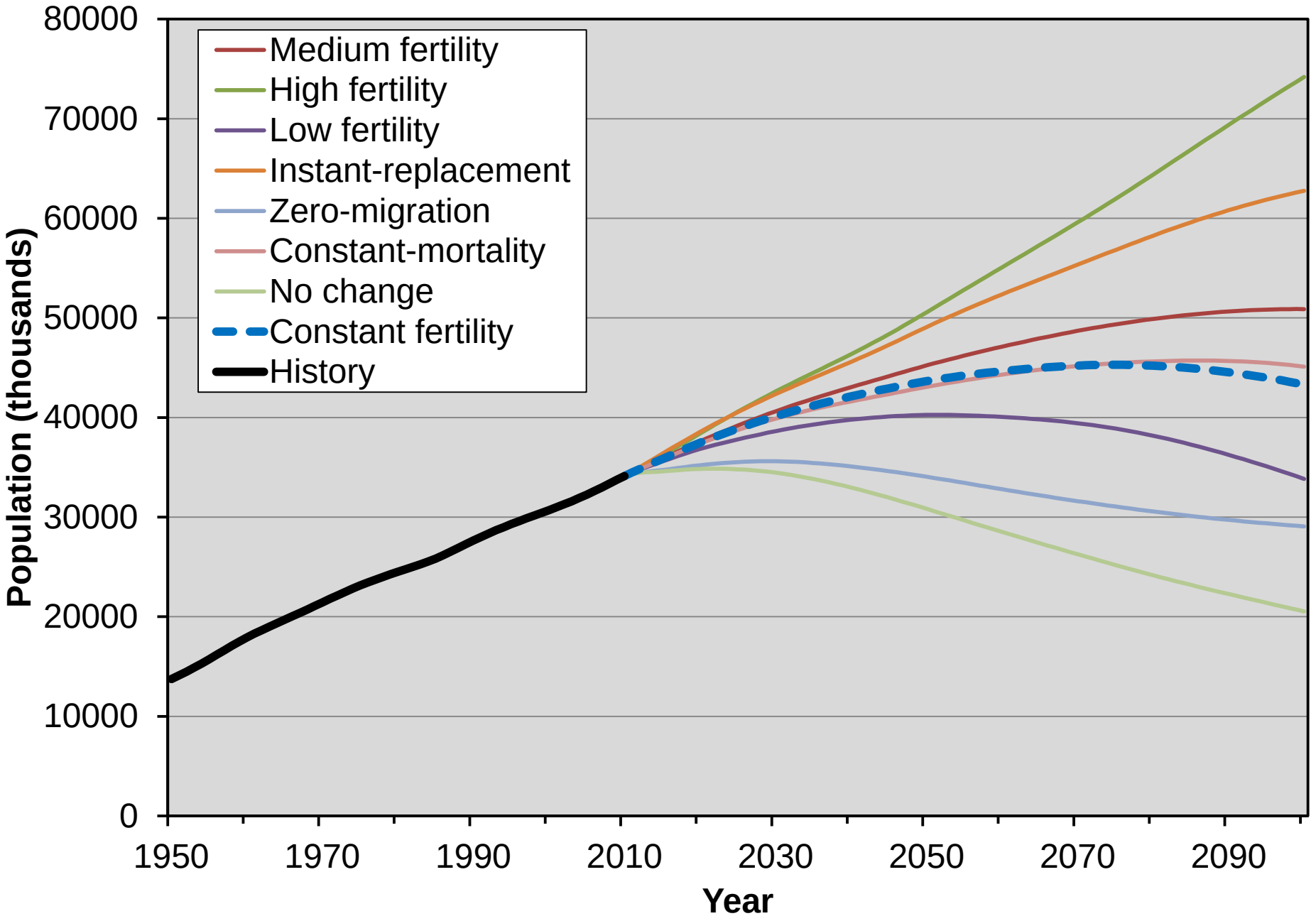
(data from BP Statistical Review 2014 and UN population statistics for 2013)

Canadian Per Capita Consumption by Fuel, 1965-2013



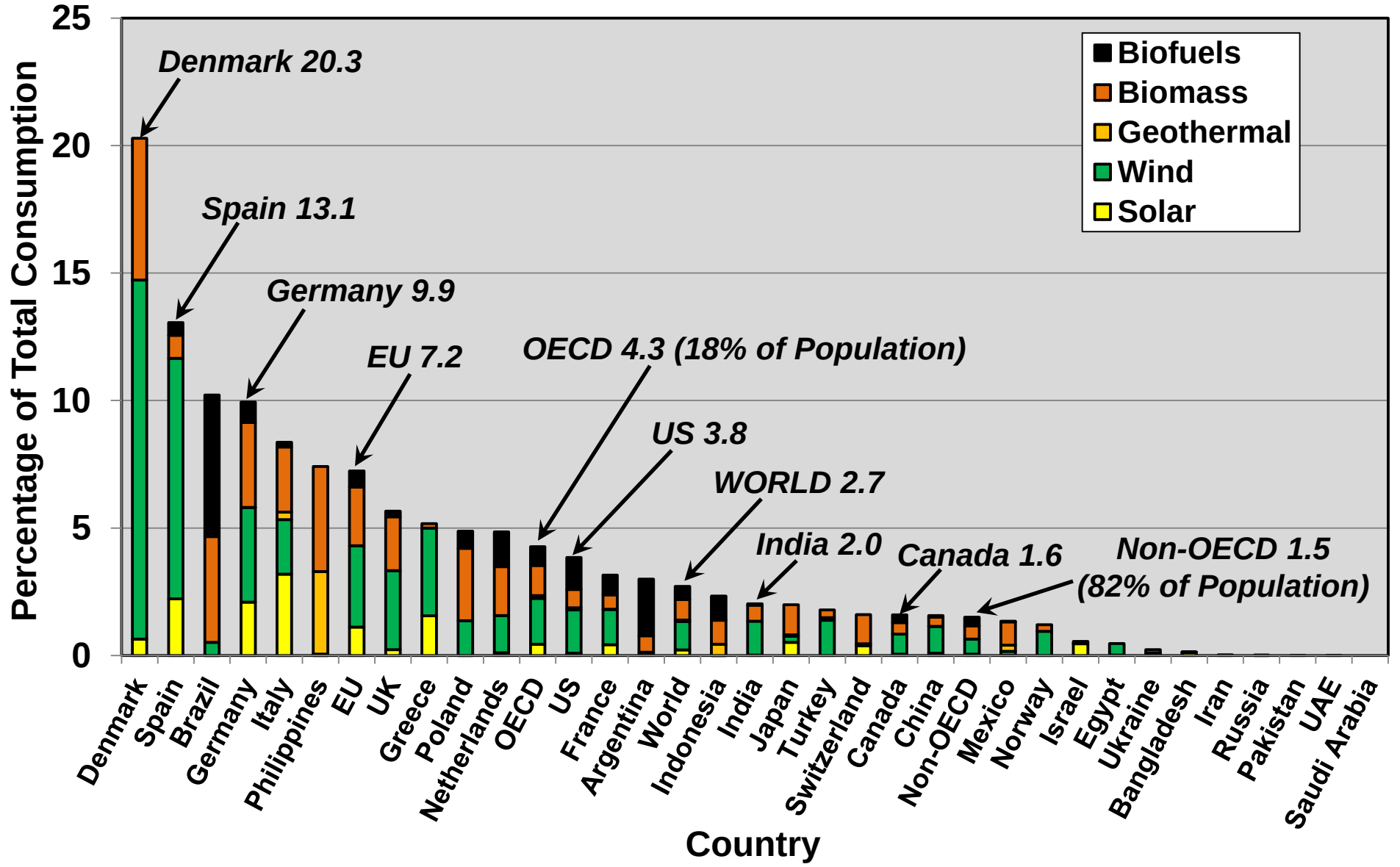
(BP Statistical Review, 2014; other renewables include wind, solar, biomass, geothermal and biofuels)

U.N. Population Projections for Canada, 1950-2100



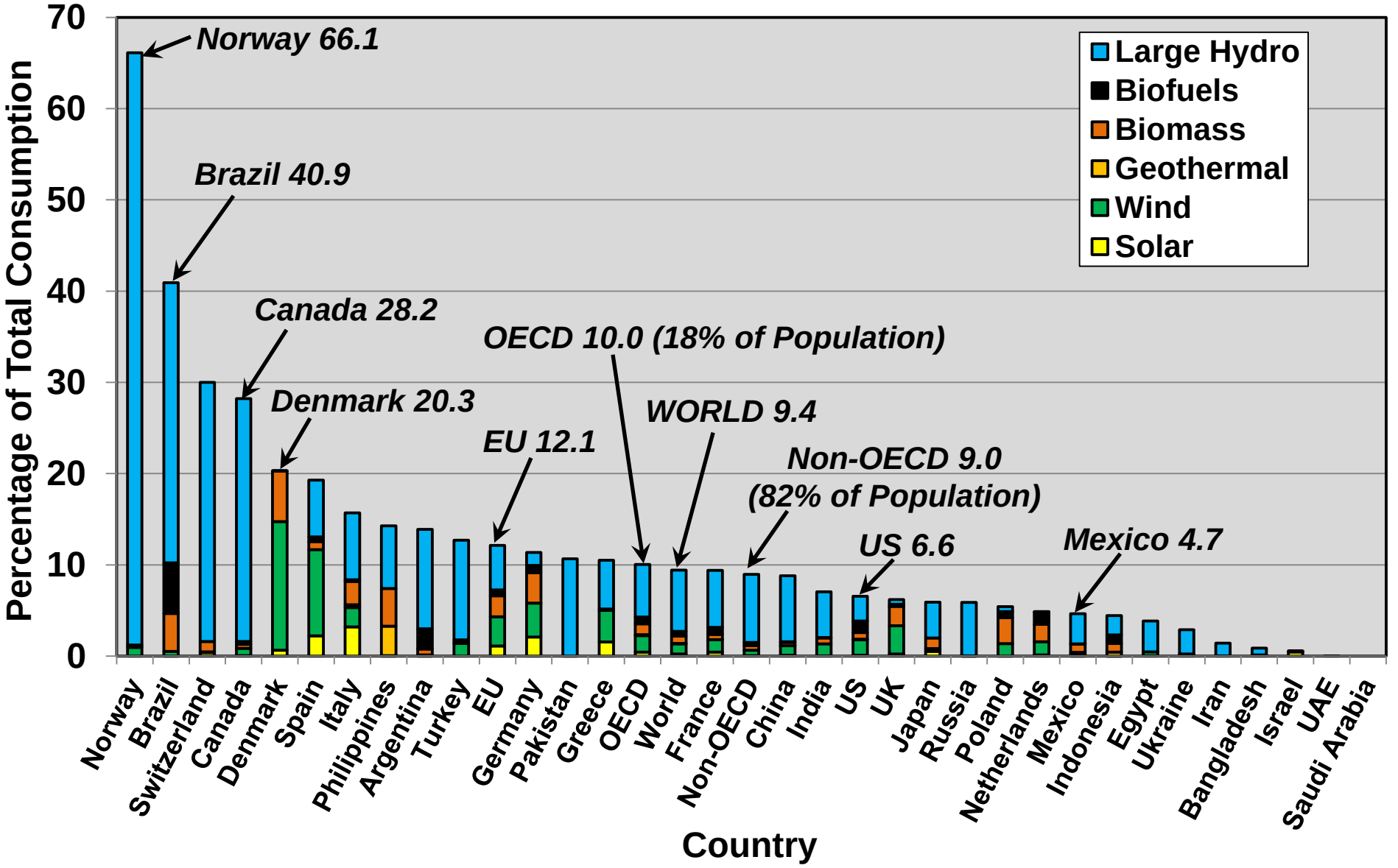
(data from U.N. World Population Prospects: The 2012 Revision)

Percentage of Primary Energy Provided by Non-Hydro Renewables by Country in 2013



(data from BP Statistical Review 2014 and UN population statistics for 2013)

Percentage of Primary Energy Provided by Non-Hydro Renewables plus Large Hydro by Country in 2013



(data from BP Statistical Review 2014)


North American shale plays
(as of May 2011)
Muskwa-Otter Park, Evie-Klua
Lower Besa River
Muskwa-Otter Park
Montney
Doig Phosphate
Colorado Group
Niobrara*
Bakken ***
Cody
Heath**
Gammon
Mowry
Hilliard- Baxter-Mancos-Niobrara
Niobrara*
Mancos
Hermosa
Monterey-Temblor
Monterey
Lewis
Pierre-Niobrara
Excello-Mulky
Woodford
Fayetteville
Bend
Avalon
Barnett
Barnett-Woodford
Eagle Ford
Eagle Ford, La Casita
Eagle Ford, Tithonian
Pimienta
Pimienta, Tamaulipas
Maltrata
Haynesville-Bossier
Tuscaloosa
Floyd-Neal
Chattanooga
Conasauga
New Albany
Antrim
Utica
Frederick Brook
Horton Bluff
Devonian (Ohio)
Marcellus
Utica
Current shale plays
Stacked plays
Shallowest / youngest
Intermediate depth / age
Deepest / oldest
* Mixed shale & chalk play
** Mixed shale & limestone play
*** Mixed shale & tight dolostone-siltstone-sandstone play
Prospective shale plays
Basins
N
Miles
0 200 400 600 800
eia

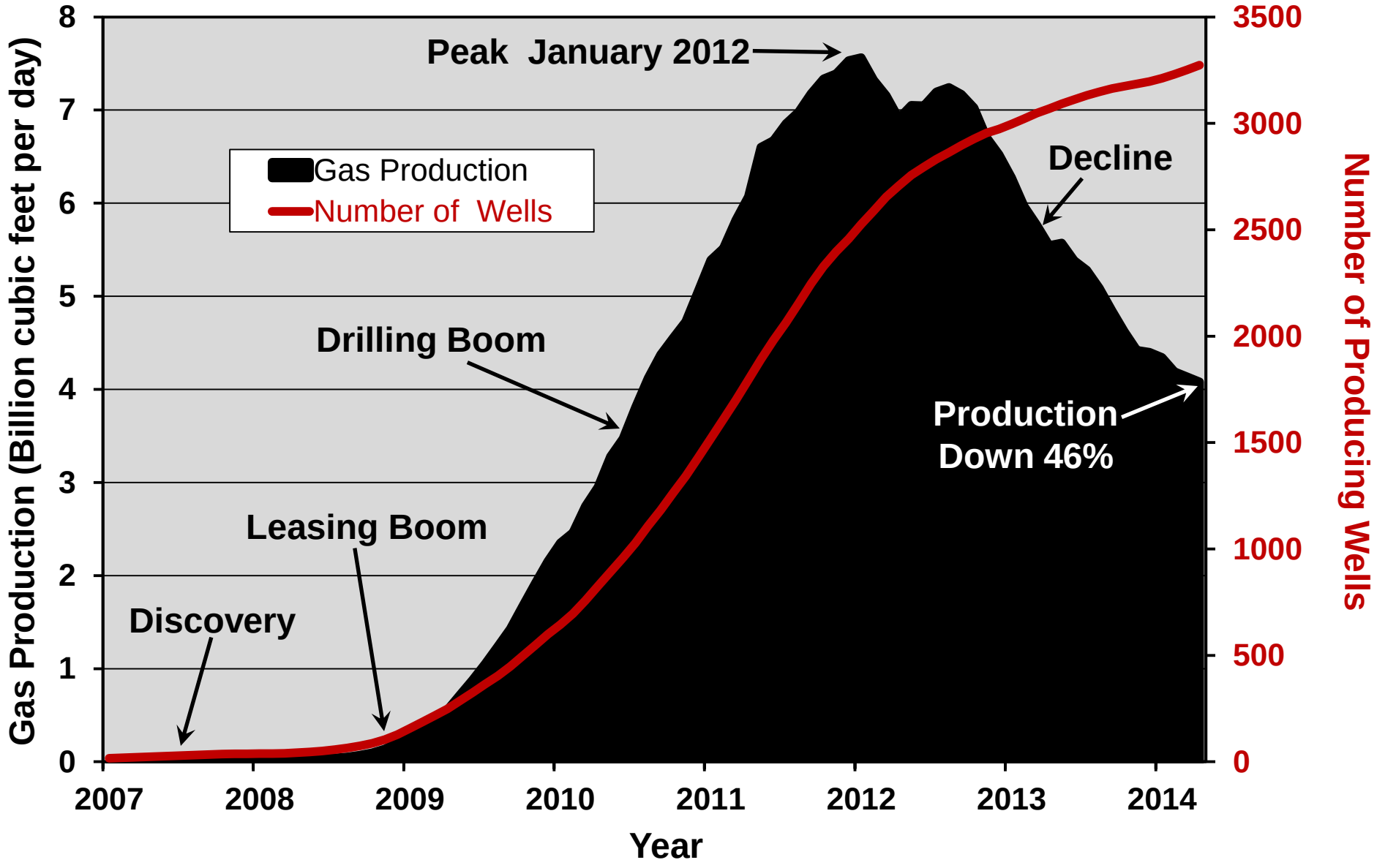
Conventional Wisdom

- The United States is on the verge of Energy Independence thanks to the “SHALE REVOLUTION”.
- Tight Oil will allow U.S. production to exceed that of Saudi Arabia and U.S. imports will shrink to zero.
- Shale Gas production will continue to grow for the foreseeable future (2040 at least) and prices will remain below $5.00/mcf for the next 10 years and below $6.00/mcf until 2030.
- Shale Gas can replace very substantial amounts of oil for transport and coal for electricity generation.
- The way is clear for U.S. LNG exports to monetize the shale bounty. Crude oil exports should be allowed to monetize tight oil production.

The Shale Play Life Cycle

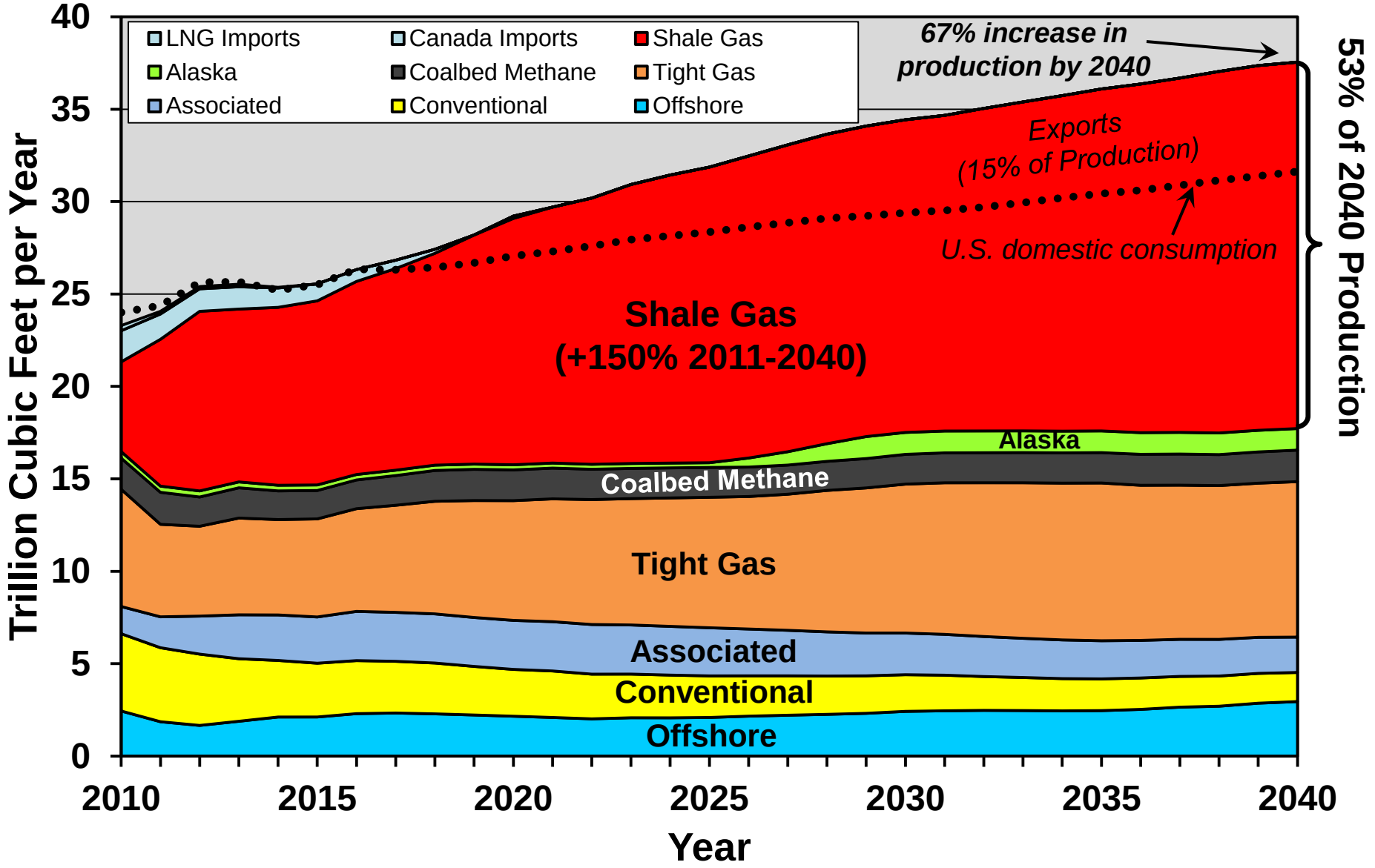
- Discovery followed by leasing frenzy.
- Drilling boom follows to meet “held-by-production” lease requirements.
- Sweet spots identified, targeted and drilled off.
- Production rises rapidly and is maintained for cash-flow despite potentially uneconomic full-cycle costs.
- Sweet spots become saturated and well quality and field production decline.
- Plays like the Haynesville become middle aged after just five years.

Haynesville Gas Production and Number of Producing Wells, 2007-2014



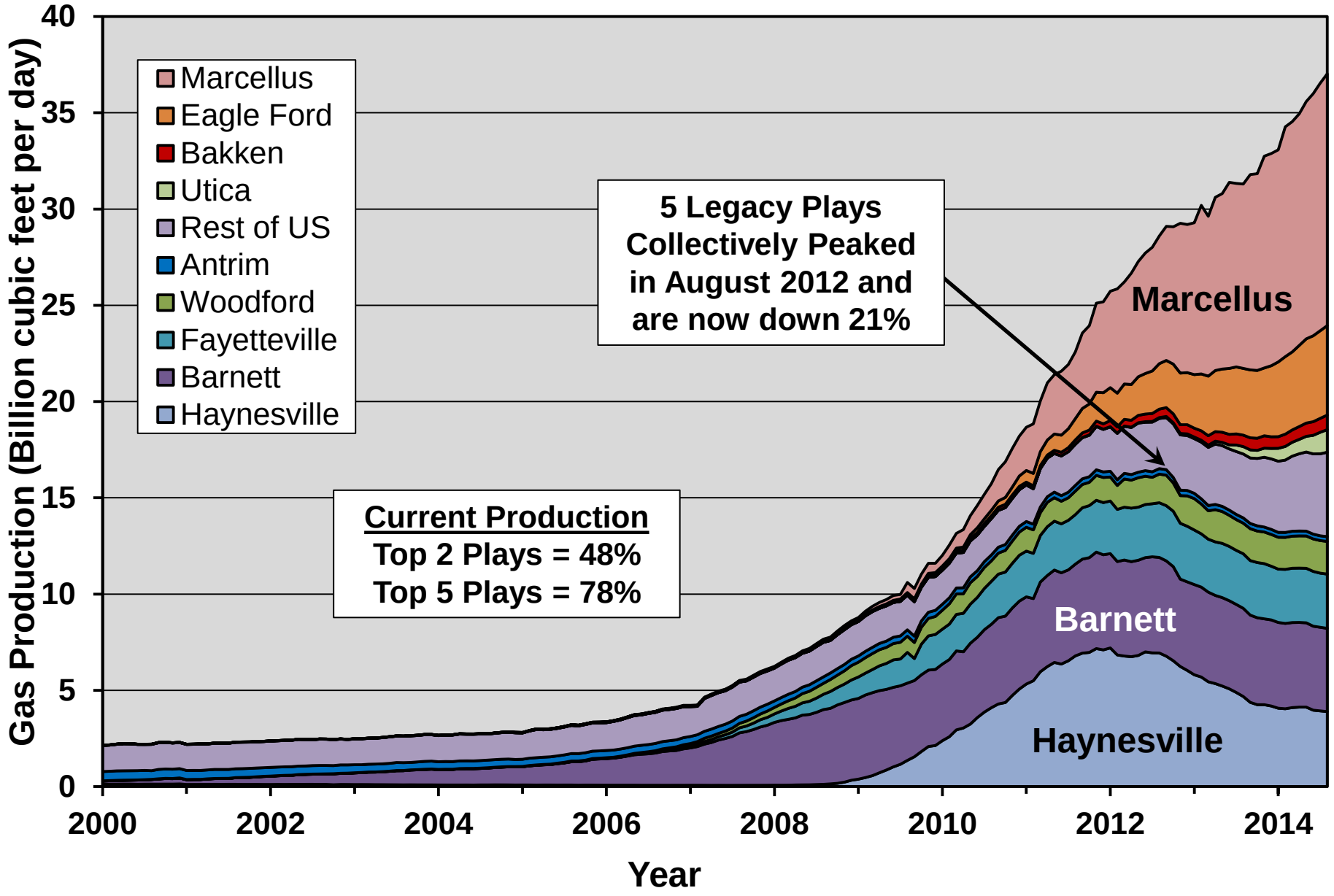
(data from Drillinginfo, August, 2014, three month trailing moving average)

U.S. Natural Gas Supply Projection by Source, 2010-2040, EIA Reference Case 2014



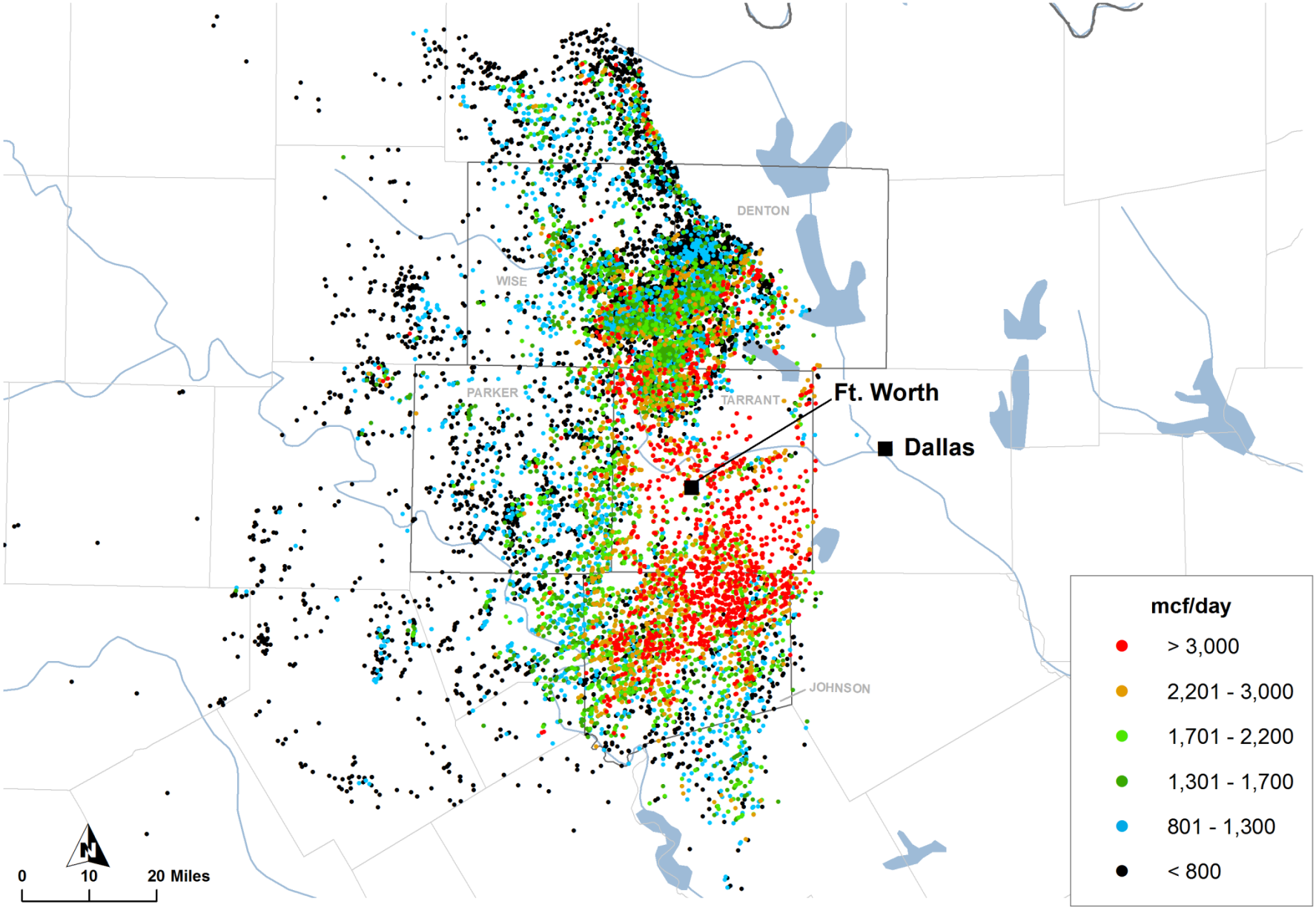
(data from EIA Annual Energy Outlook 2014, Tables 13 and 14, http://www.eia.gov/forecasts/aeo/er/excel/yearbyyear.xlsx)

U.S. Shale Gas Production by Play, 2000-2014



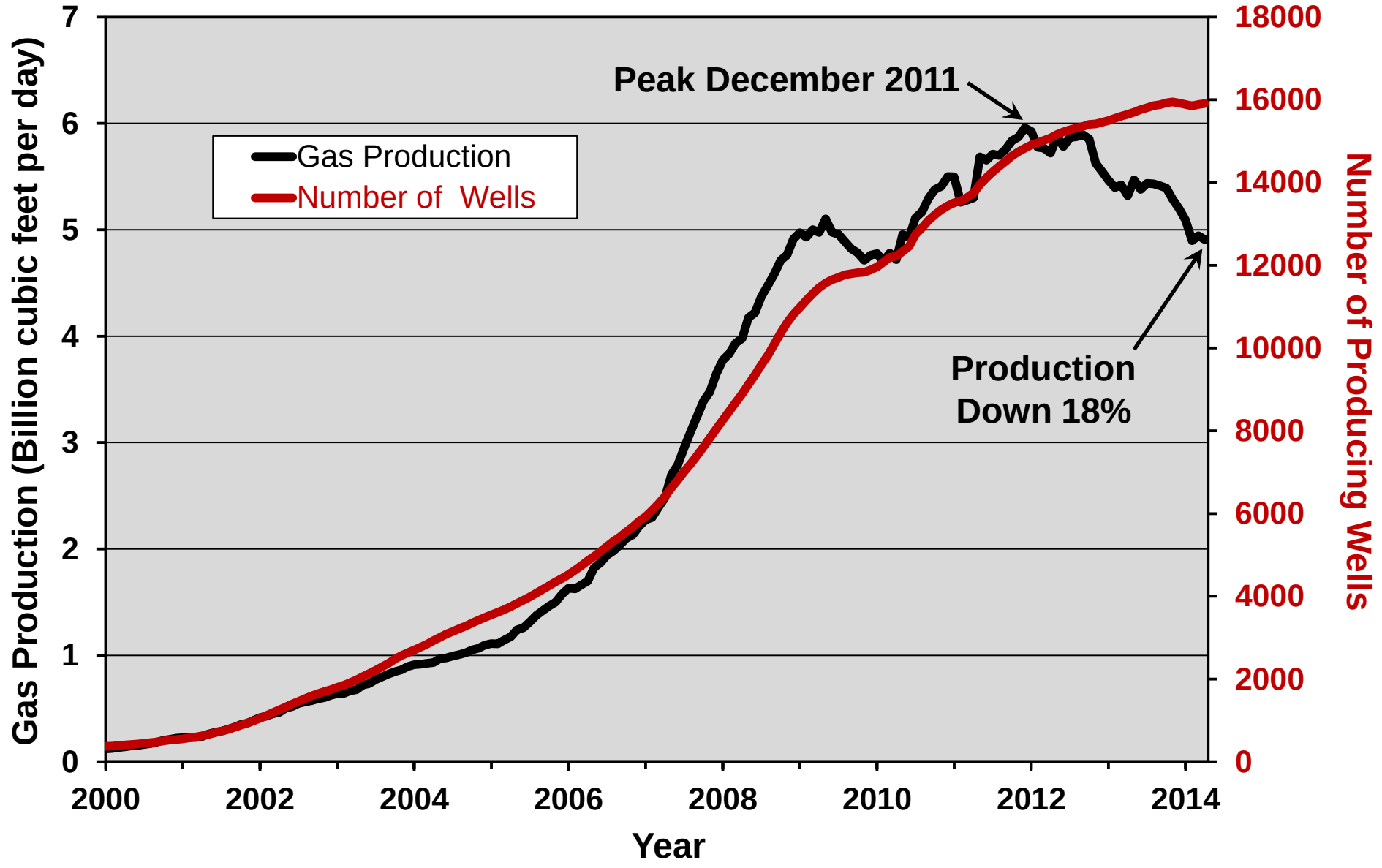
(data from EIA Natural Gas Weekly Update, September 24, 2014)

Barnett Play – Well Quality by Initial Gas Production



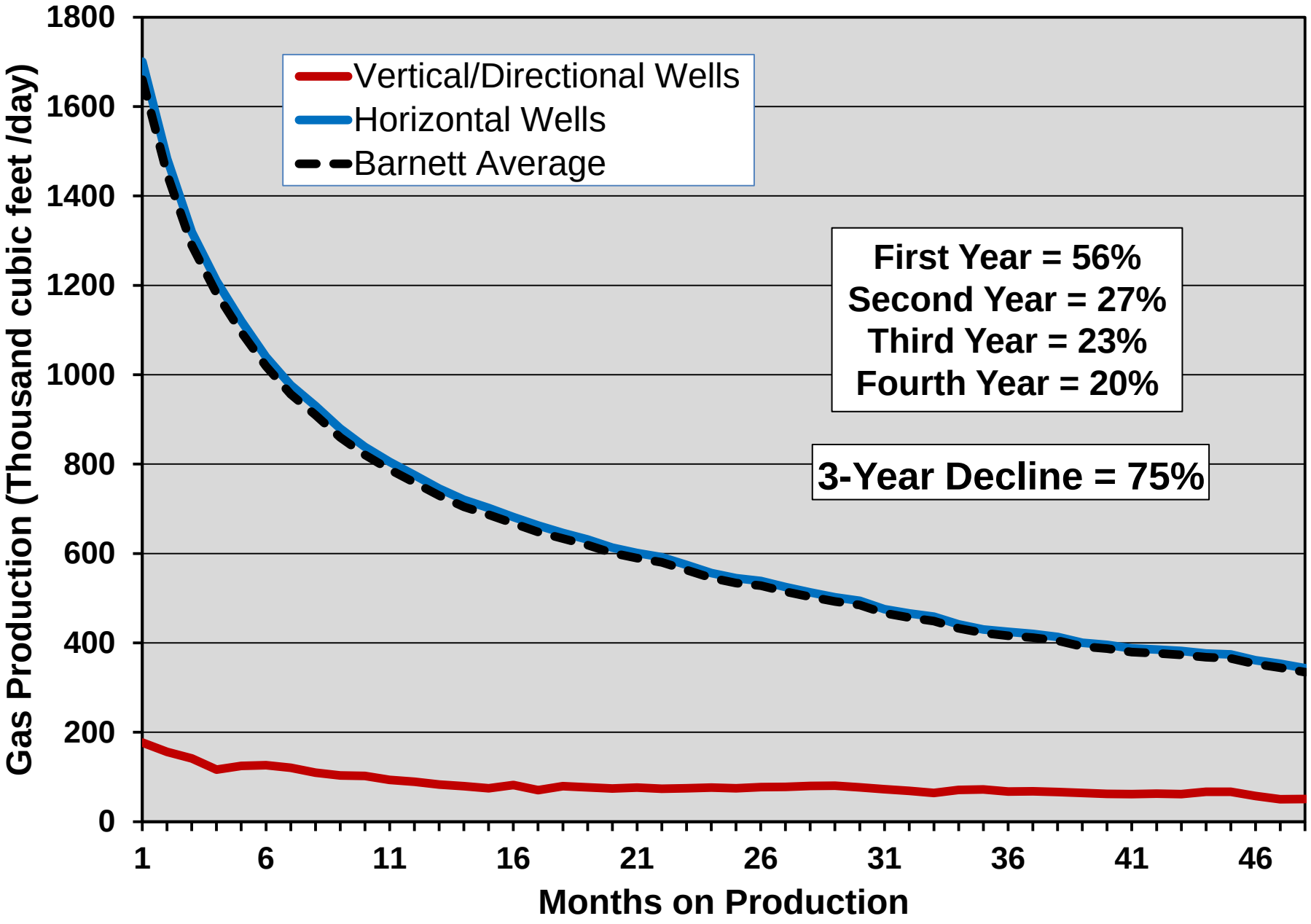
(map by John Van Hoesen based on data from Drillinginfo, August, 2014)

Barnett Gas Production and Number of Producing Wells, 2000-2014



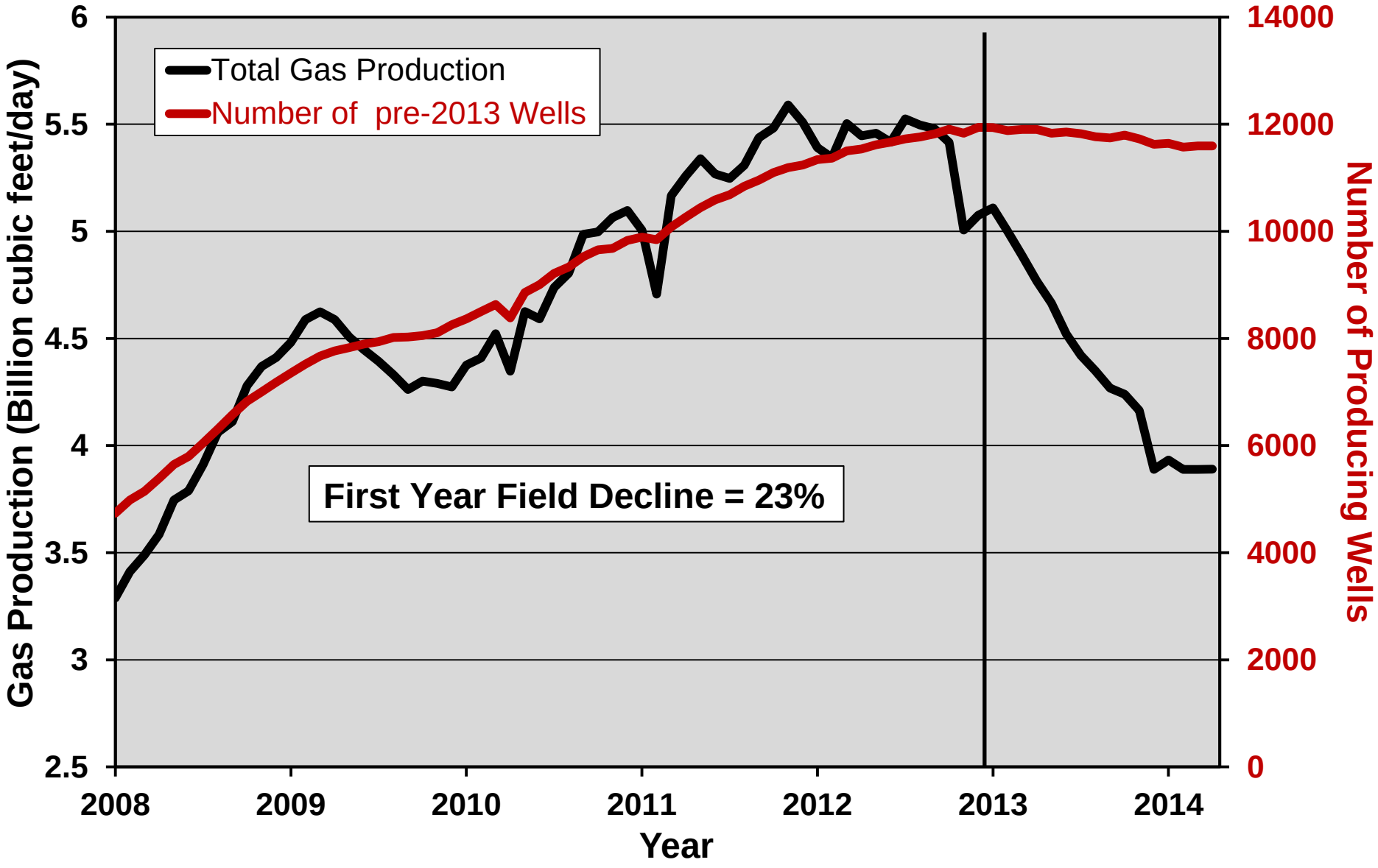
(data from Drillinginfo, August, 2014, three month trailing moving average)

Barnett Average Gas Well Decline Curves by Well Type



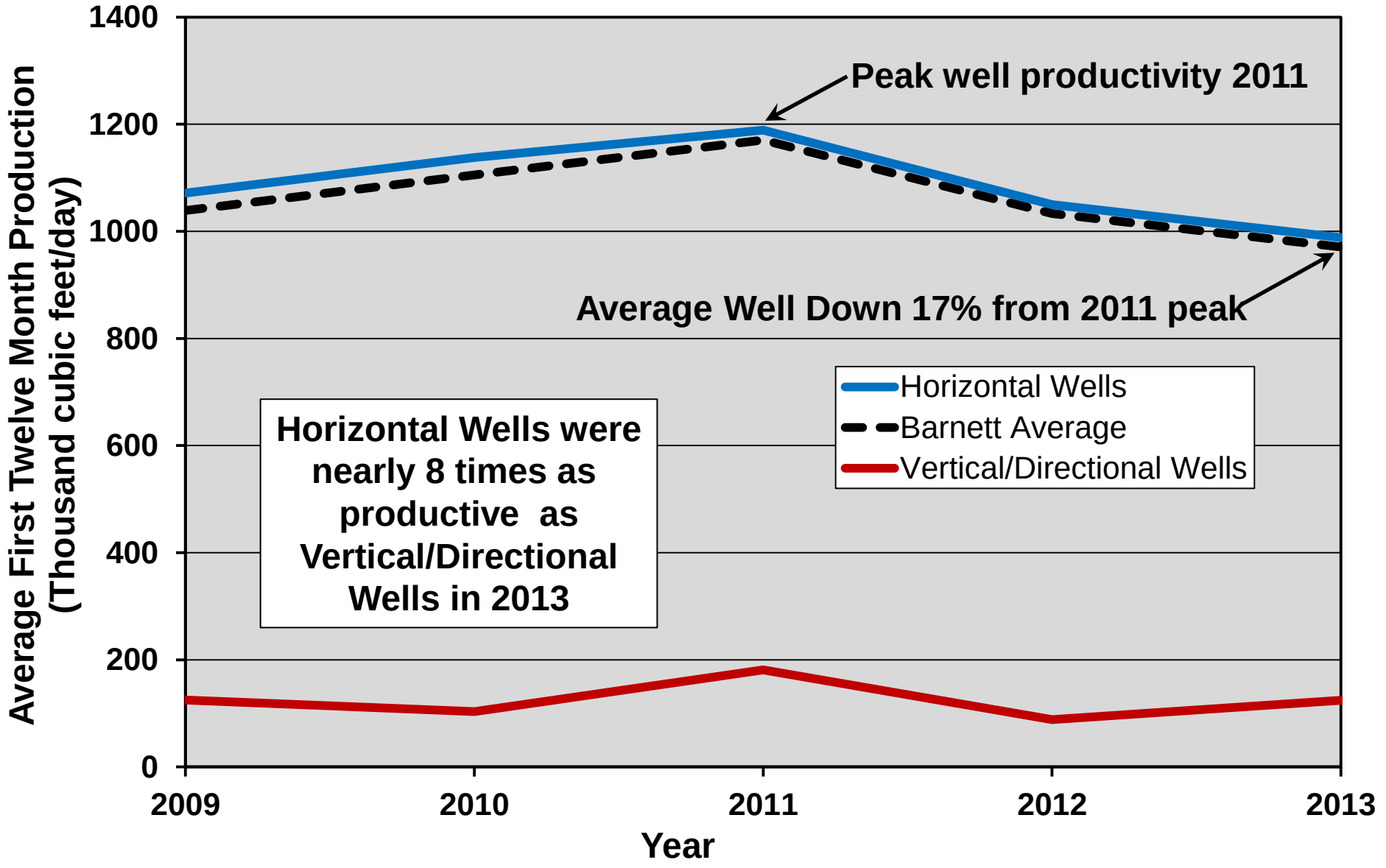
(data from Drillinginfo, August, 2014)

Barnett Field Decline – Gas Production from Horizontal Wells Drilled Prior to 2013



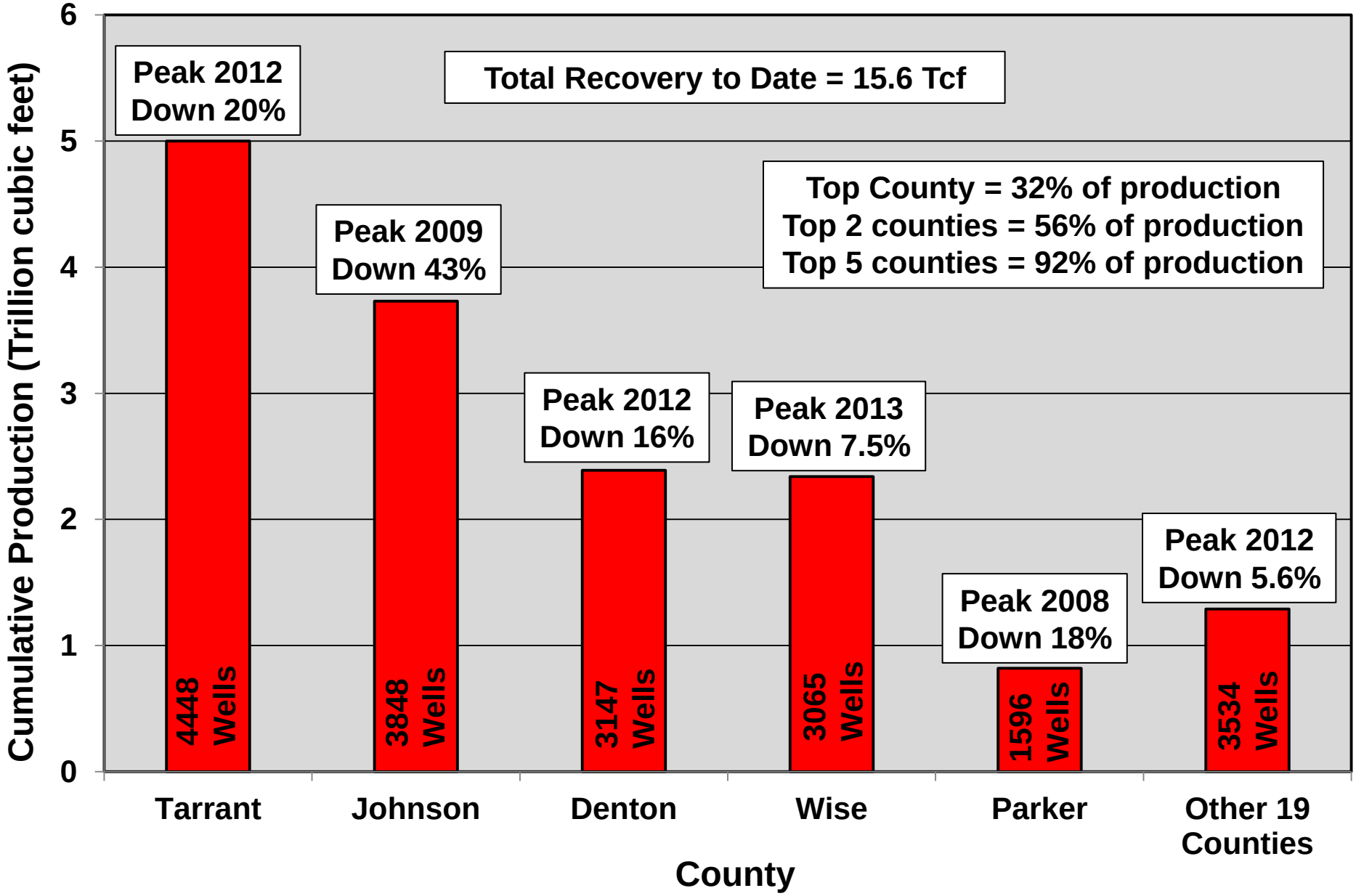
(data from Drillinginfo, August, 2014)

Barnett Gas Well Productivity by Well Type, Average Production over First Twelve Months, 2009-2013



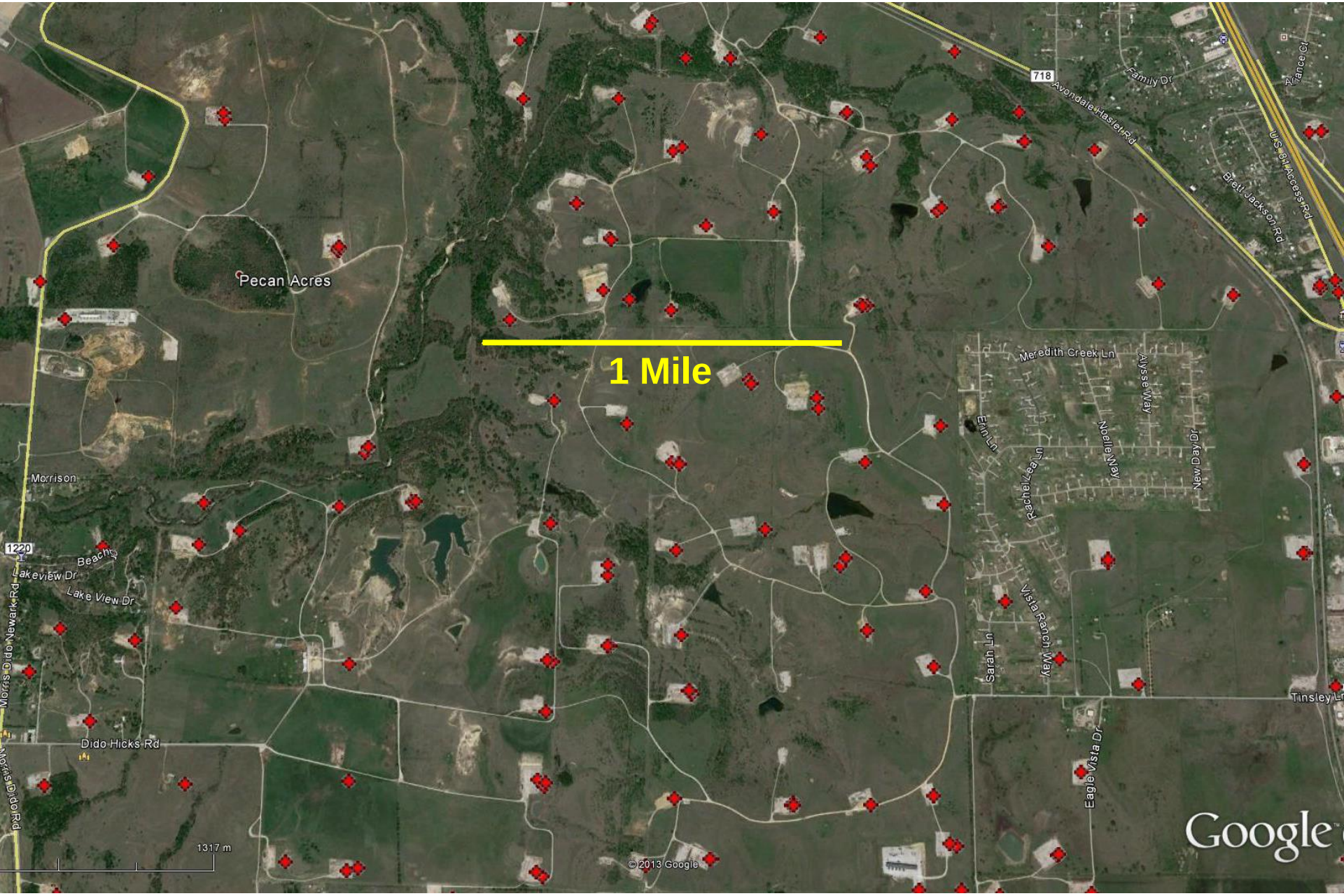
(data from Drillinginfo, August, 2014)

Barnett Cumulative Gas Production By County



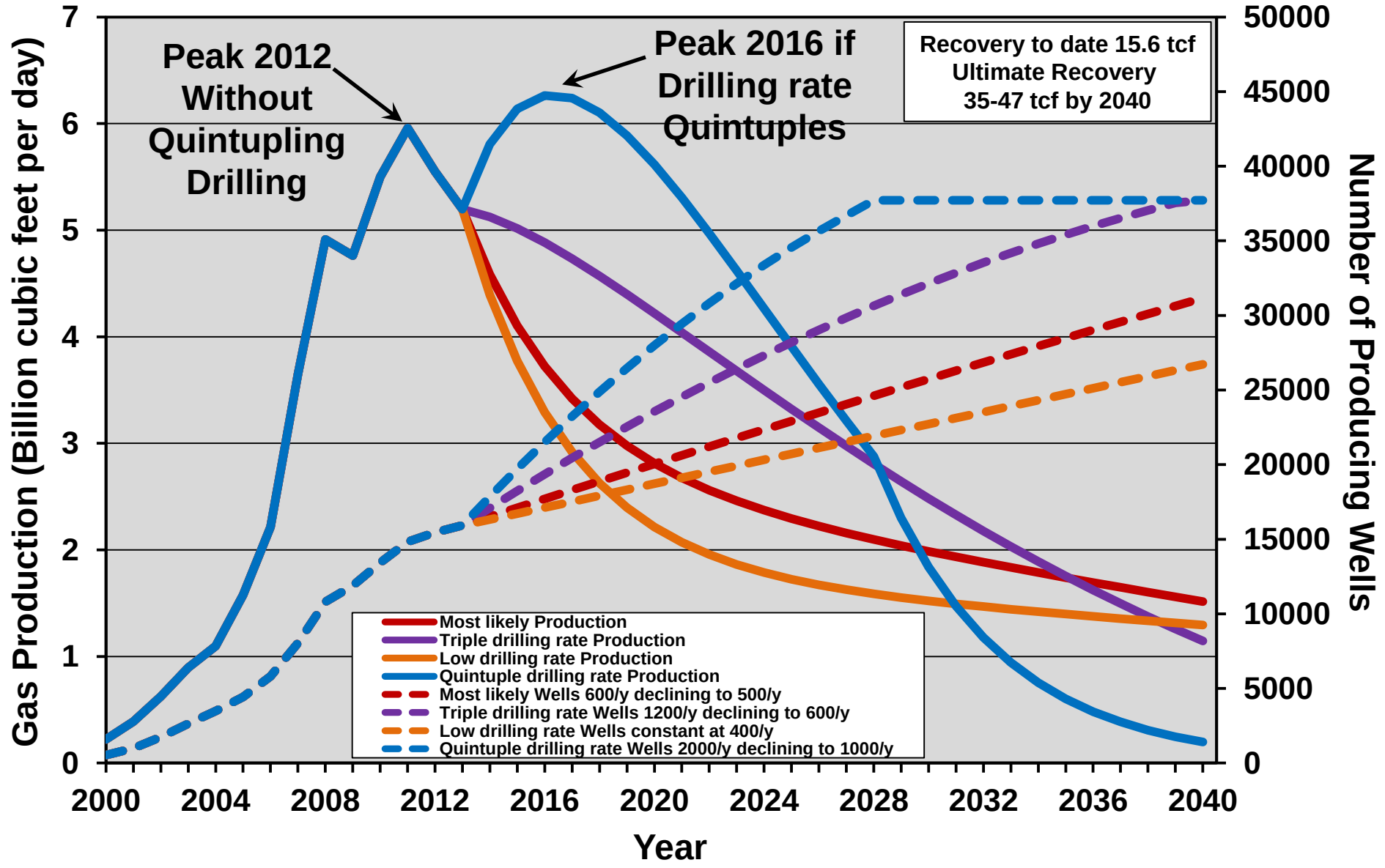
(data from Drillinginfo, August, 2014)

Tarrant County Well Footprint



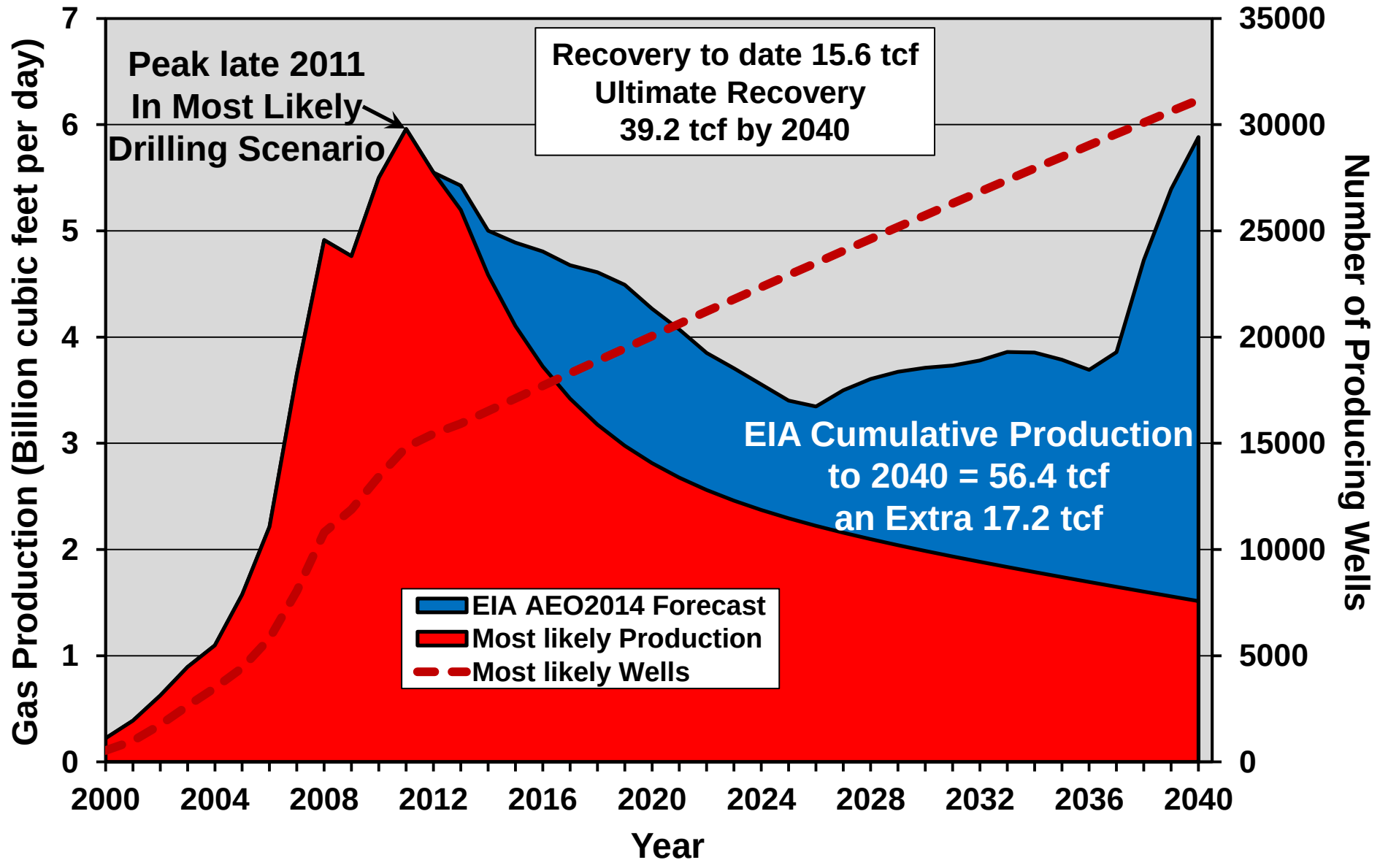
(data from Drillinginfo, February, 2014)

Barnett Gas Production Forecast in various Drilling Rate Scenarios through 2040



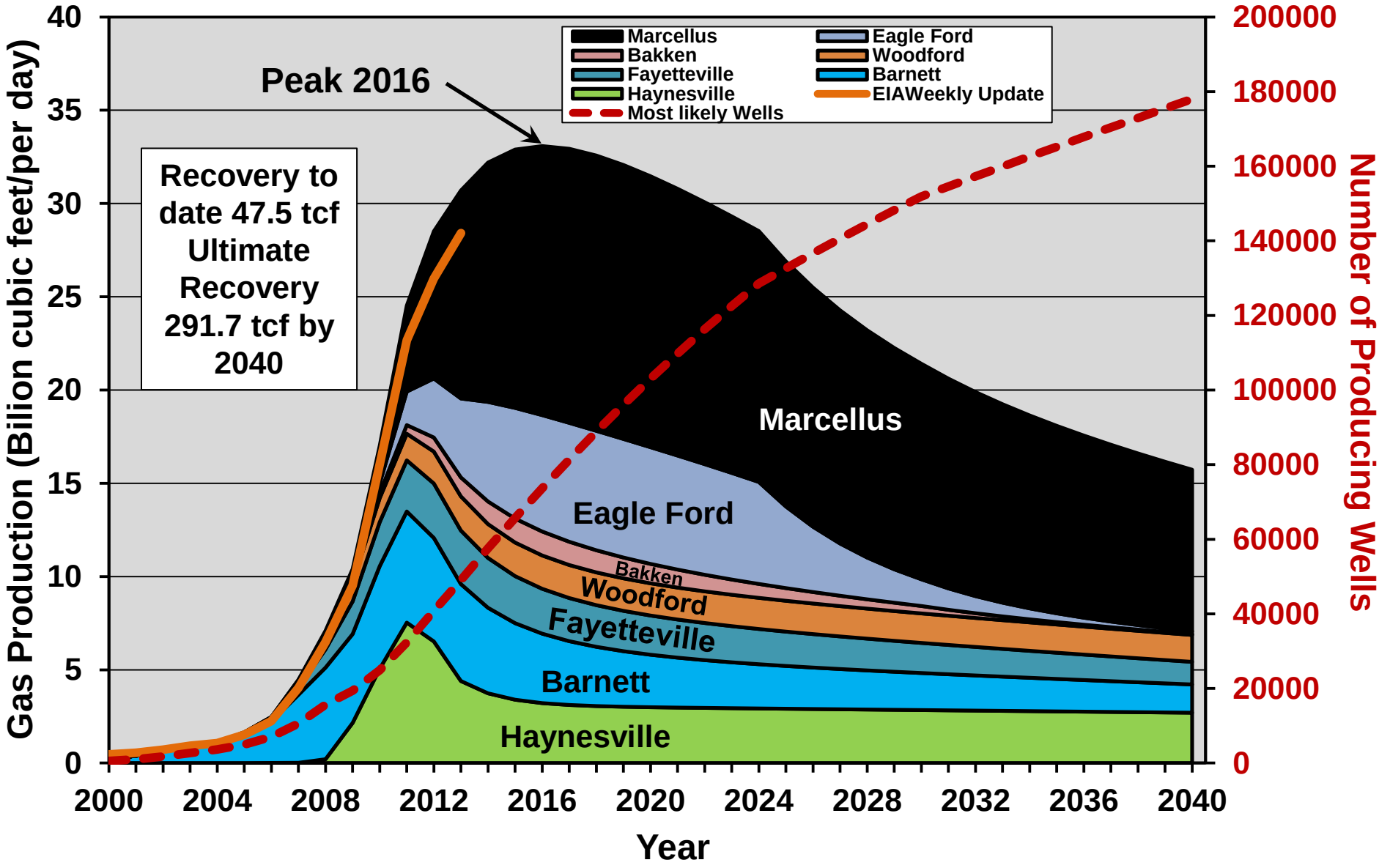
(data from Drillinginfo, August, 2014,

Barnett Gas Production Forecast in the Most Likely Drilling Rate Scenario vs EIA AEO2014 projection through 2040



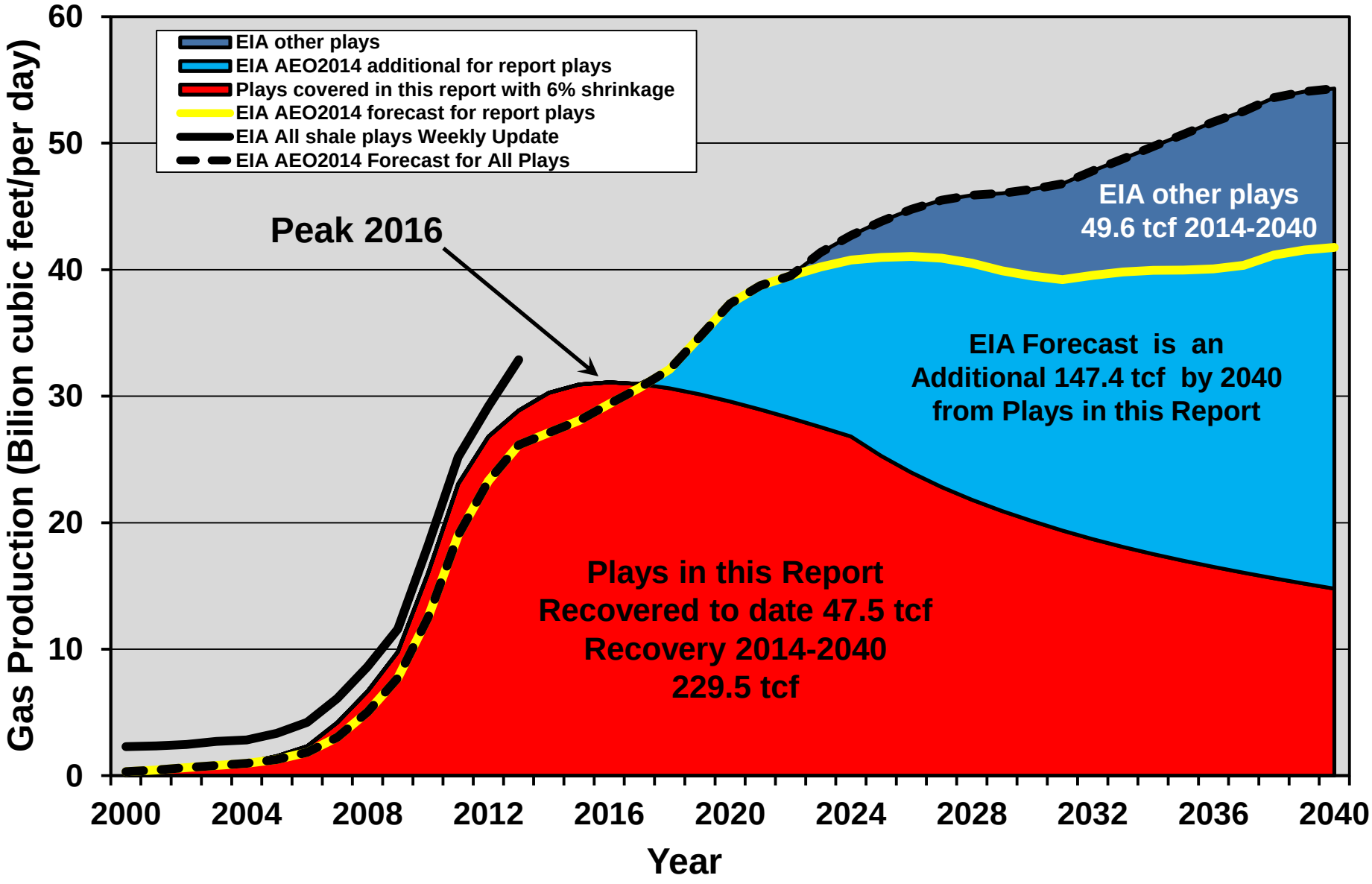
(data from Drillinginfo, August, 2014,

Most Likely Drilling Rate Gas Production from Major Shale Plays through 2040



(data from Drillinginfo, September, 2014,

Most Likely Drilling Rate Gas Production from Major Shale Plays through 2040 (applying 6% shrinkage)



(data from Drillinginfo, September, 2014,

Shale Takeaways

- High field decline rates mandate sustained high levels of drilling to maintain production.
- Shale gas production from seven plays constituting 89% of production is likely to peak in 2017-2018 timeframe, depending on drilling rates.
- Tight oil production from the top two plays constituting 62% of production is likely to peak in 2016-2017 timeframe.
- Increasing drilling rates significantly over current levels will increase immediate supply and peak production levels and will move peak forward but results in steeper declines after peak – basically making the supply situation worse post-peak.
- High quality shale plays are not ubiquitous:
  - *89% of shale gas production comes from 7 of 30 plays.*
  - *82% of tight oil production comes from 7 of 21 plays.*

2013 B.C. Throne Speech

- We have a [natural gas] surplus that can meet the real and pressing needs of other economies, especially those on our Pacific doorstep. In doing so, ***we can help protect our planet***.

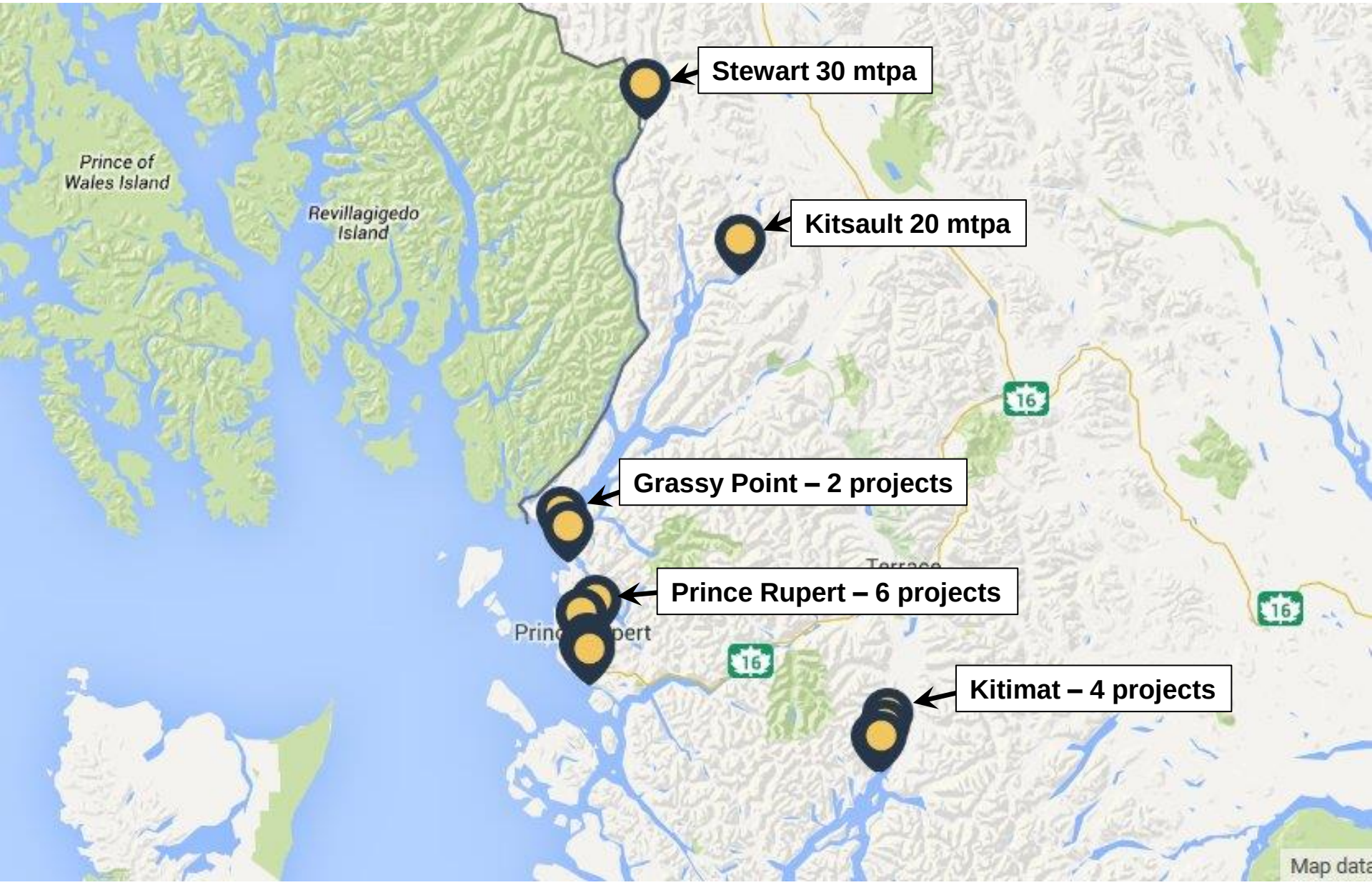
- Once all facilities reach full production, there could be over ***75,000 new annual full time jobs***.

- For our province, two new major revenue streams can be created. To protect this second stream of revenue for generations to come, your government is establishing the **British Columbia Prosperity Fund**. This could ***exceed one hundred billion dollars*** over the next 30 years.

- Whether it is ***eliminating the provincial sales tax***, or making long-term investments in areas like education or vital infrastructure that strengthen communities – these are the kinds of opportunities the B.C. Prosperity Fund can provide.

(B.C. Speech from the Throne, Globe and Mail, February 12, 2013)

Northern BC Proposed LNG Terminals

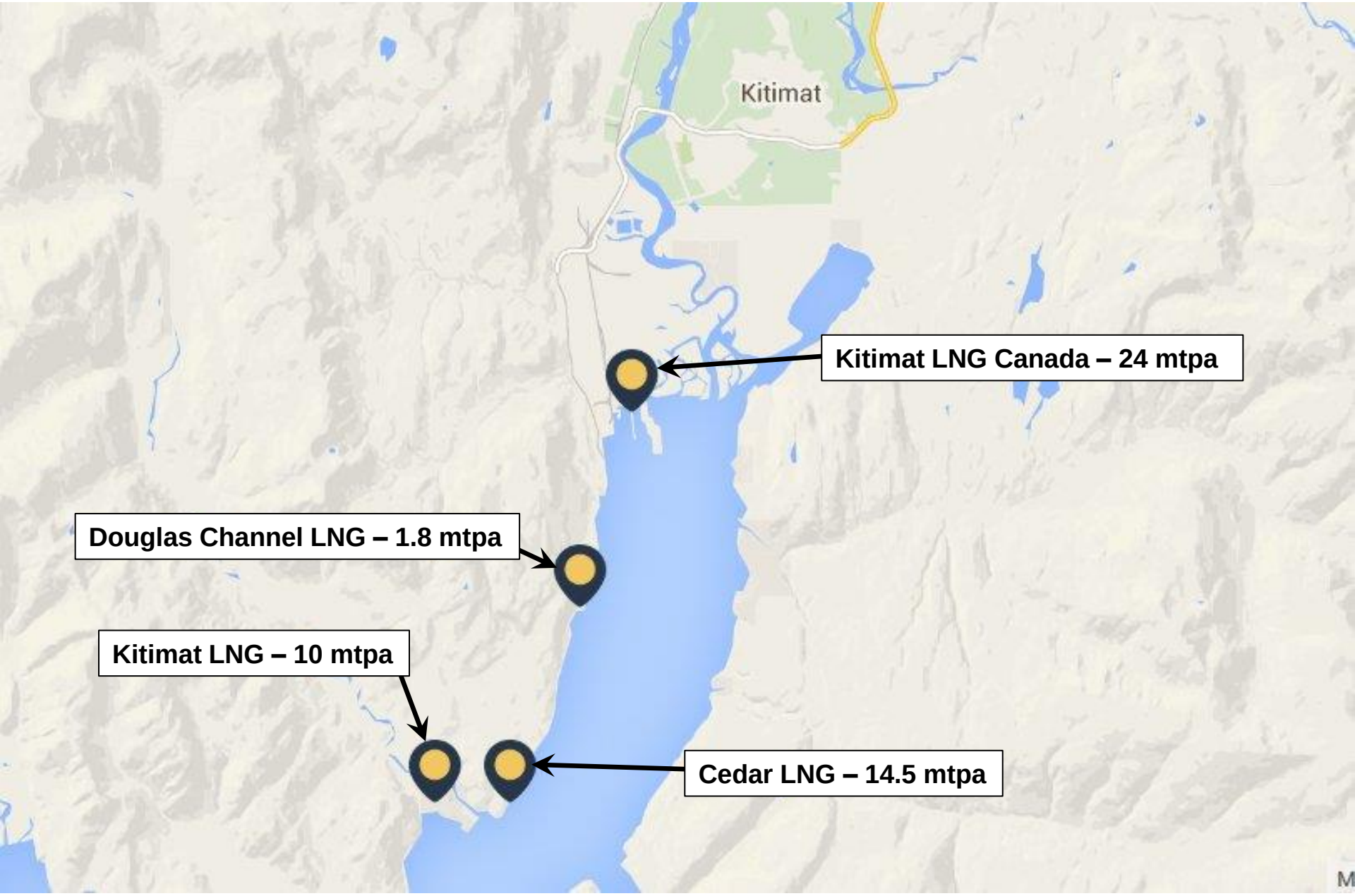


(map from http://engage.gov.bc.ca/lnginbc/lng-projects/)

Prince Rupert Area Proposed LNG Terminals

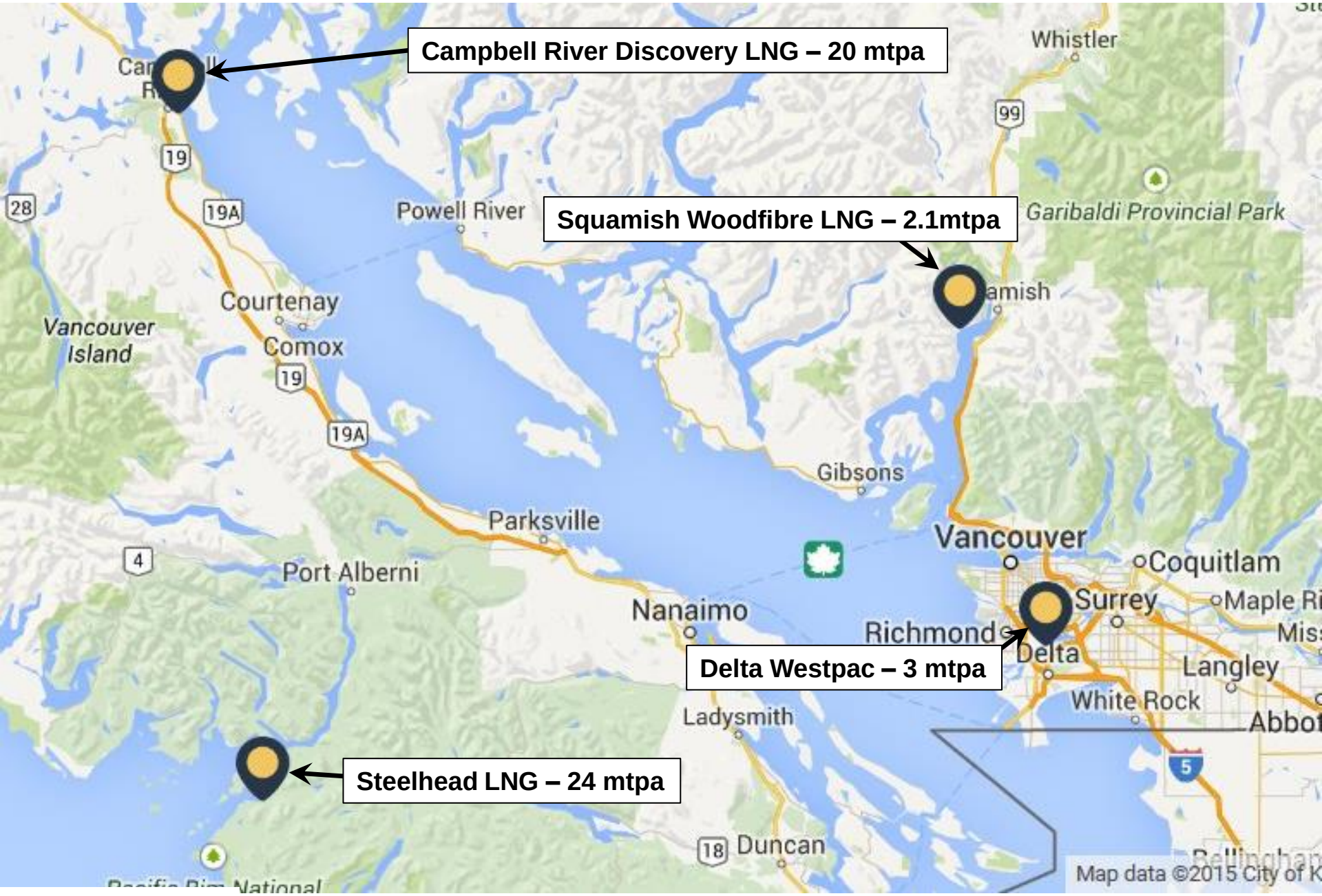
(map from http://engage.gov.bc.ca/lnginbc/lng-projects/)

Kitimat Area Proposed LNG Terminals



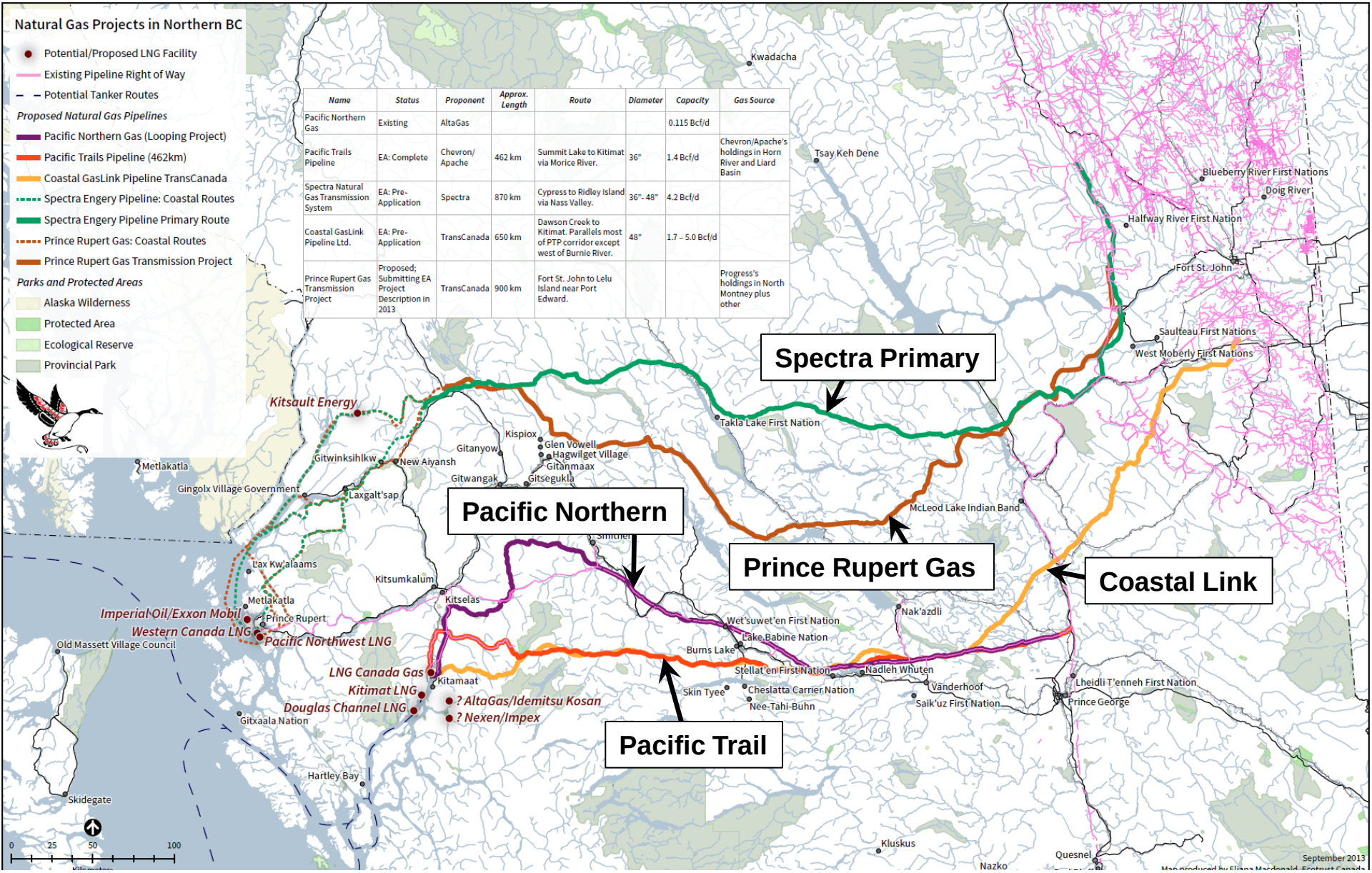
(map from http://engage.gov.bc.ca/lnginbc/lng-projects/)

Southern BC Proposed LNG Terminals



(map from http://engage.gov.bc.ca/lnginbc/lng-projects/)

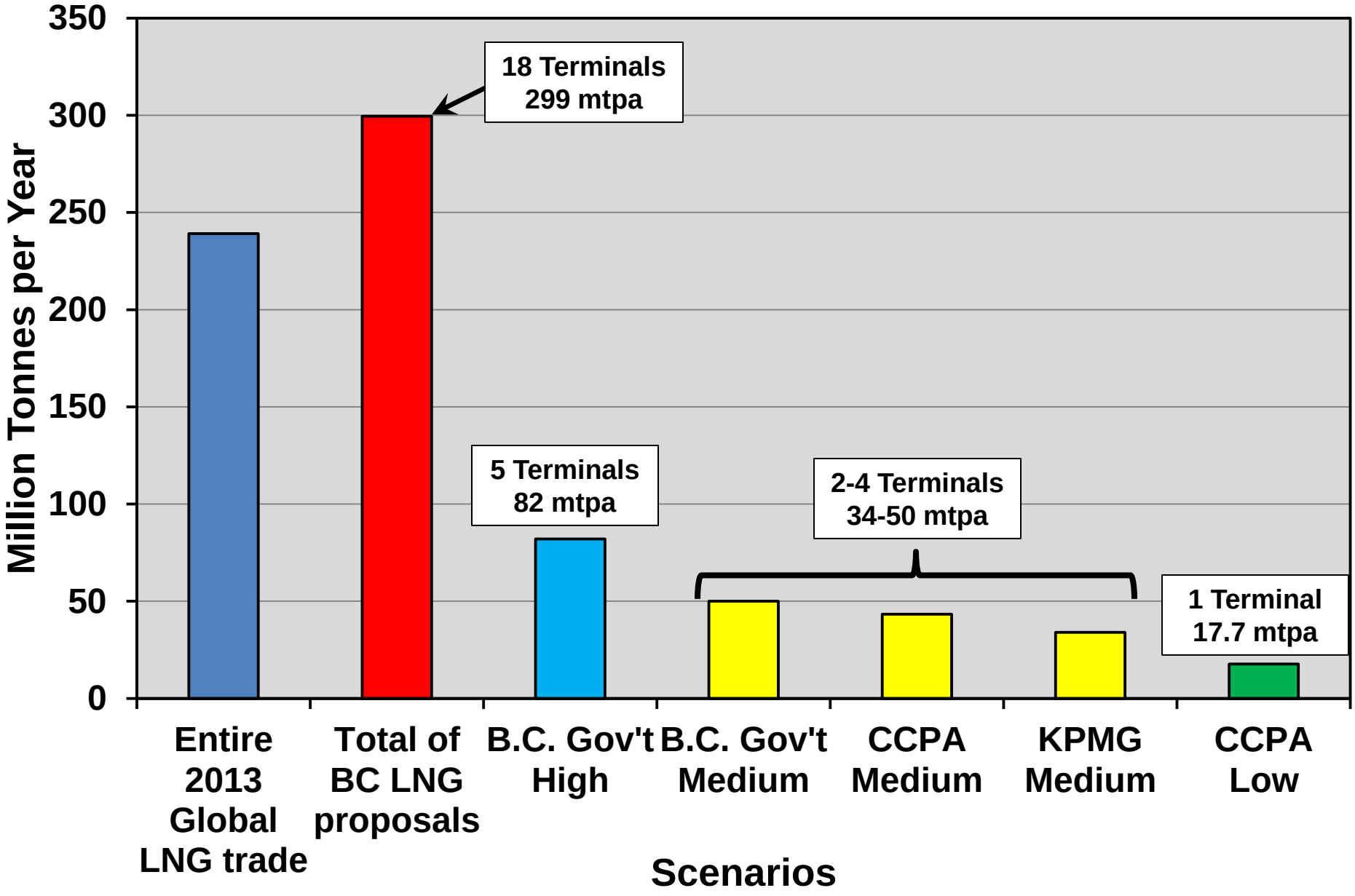
Northern BC Proposed LNG Pipeline Projects



Name	Status	Proponent	Approx. Length	Route	Diameter	Capacity	Gas Source
Pacific Northern Gas	Existing	AltaGas				0.115 Bcf/d	
Pacific Trails Pipeline	EA: Complete	Chevron/ Apache	462 km	Summit Lake to Kitimat via Morice River.	36"	1.4 Bcf/d	Chevron/Apache's holdings in Horn River and Liard Basin
Spectra Natural Gas Transmission System	EA: Pre-Application	Spectra	870 km	Cypress to Ridley Island via Nass Valley.	36"- 48"	4.2 Bcf/d	
Coastal GasLink Pipeline Ltd.	EA: Pre-Application	TransCanada	650 km	Dawson Creek to Kitimat. Parallels most of PTP corridor except west of Burnie River.	48"	1.7 – 5.0 Bcf/d	
Prince Rupert Gas Transmission Project	Proposed; Submitting EA Project Description in 2013	TransCanada	900 km	Fort St. John to Lelu Island near Port Edward.			Progress's holdings in North Montney plus other

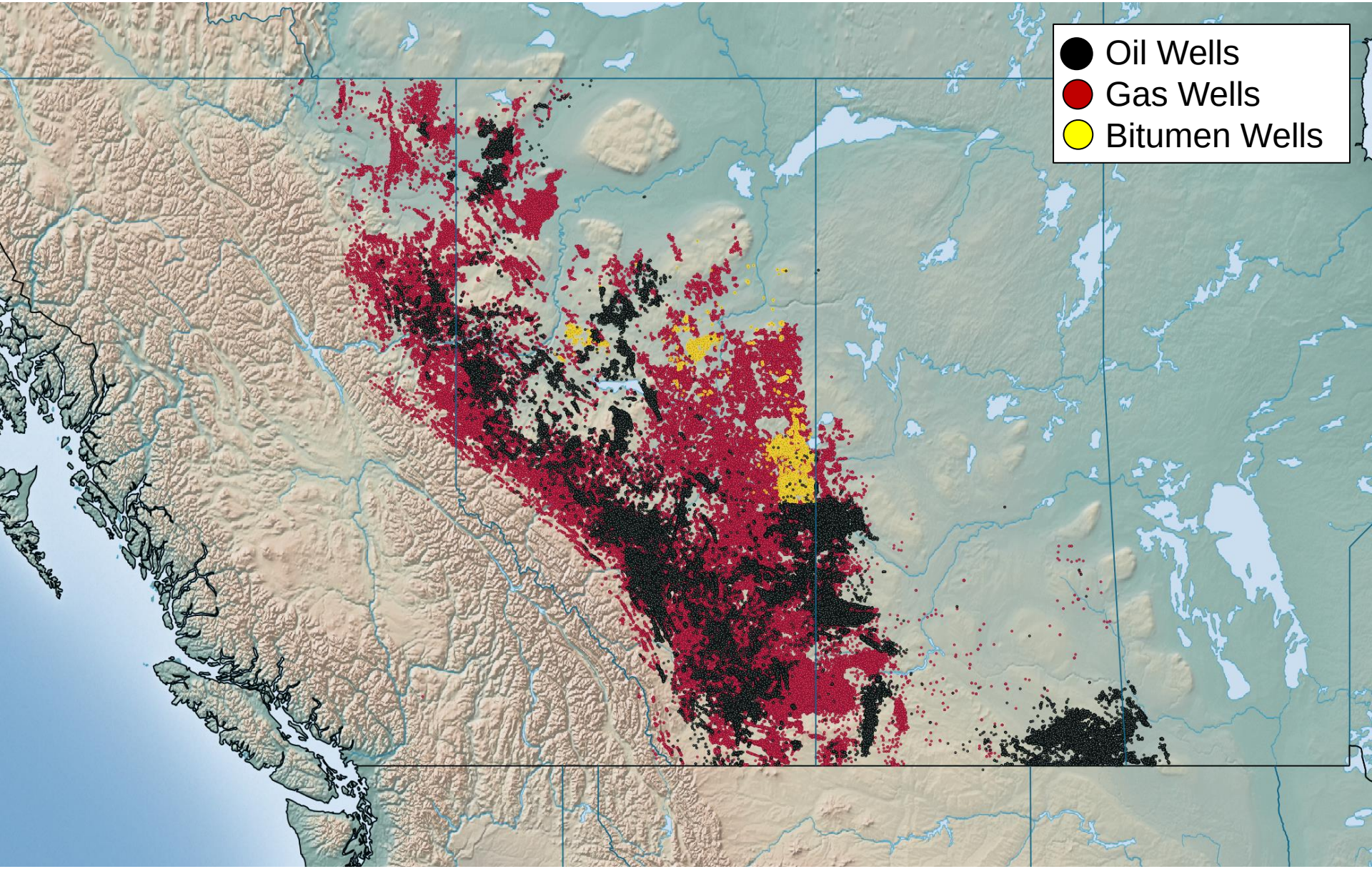
(map from BCLNGinfo.com)

Global LNG Trade compared to B.C. LNG Scenarios



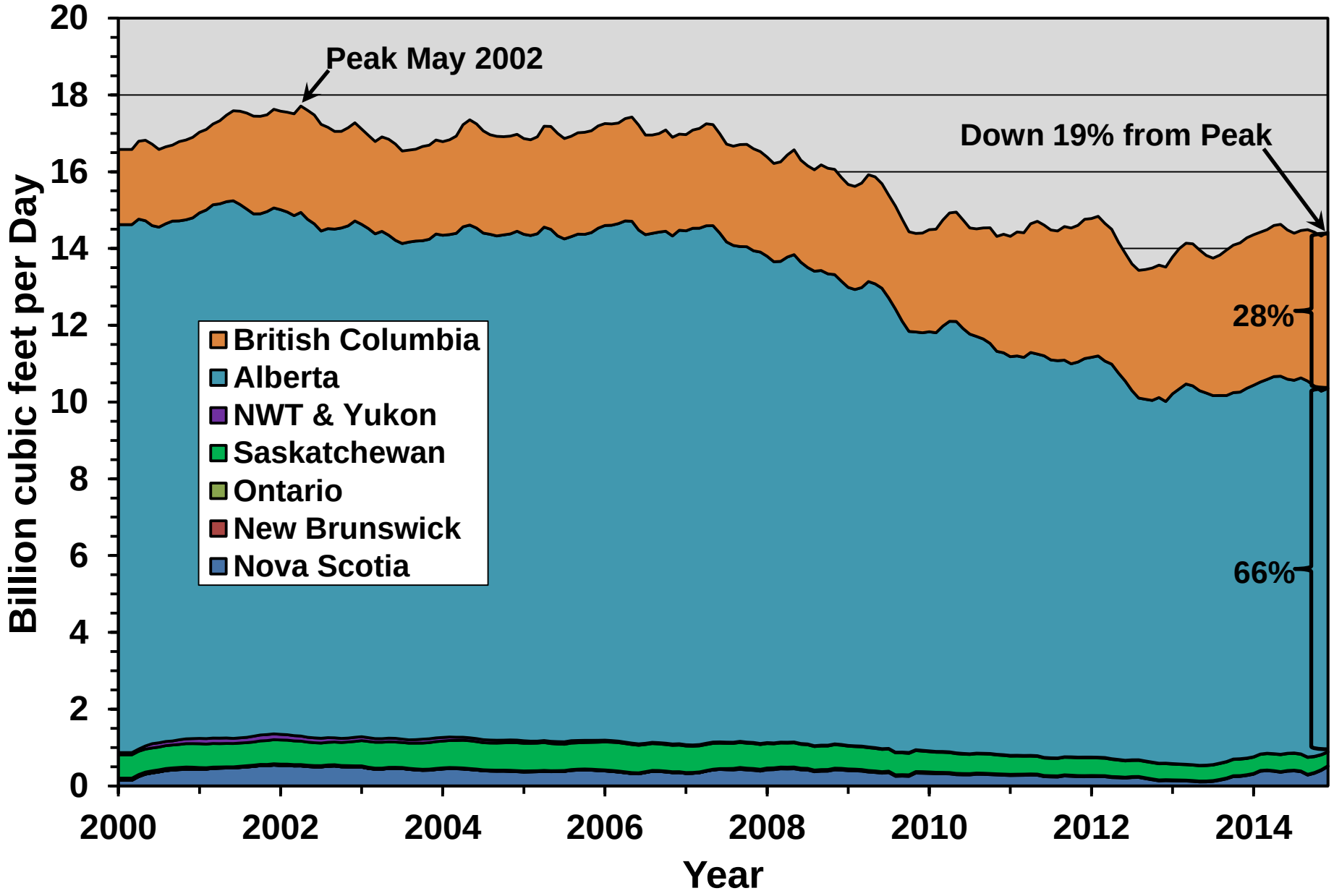
(B.C. Government literature, CCPA)

Western Canada, Distribution of Wells with Current or Historical Production, 1950-2014



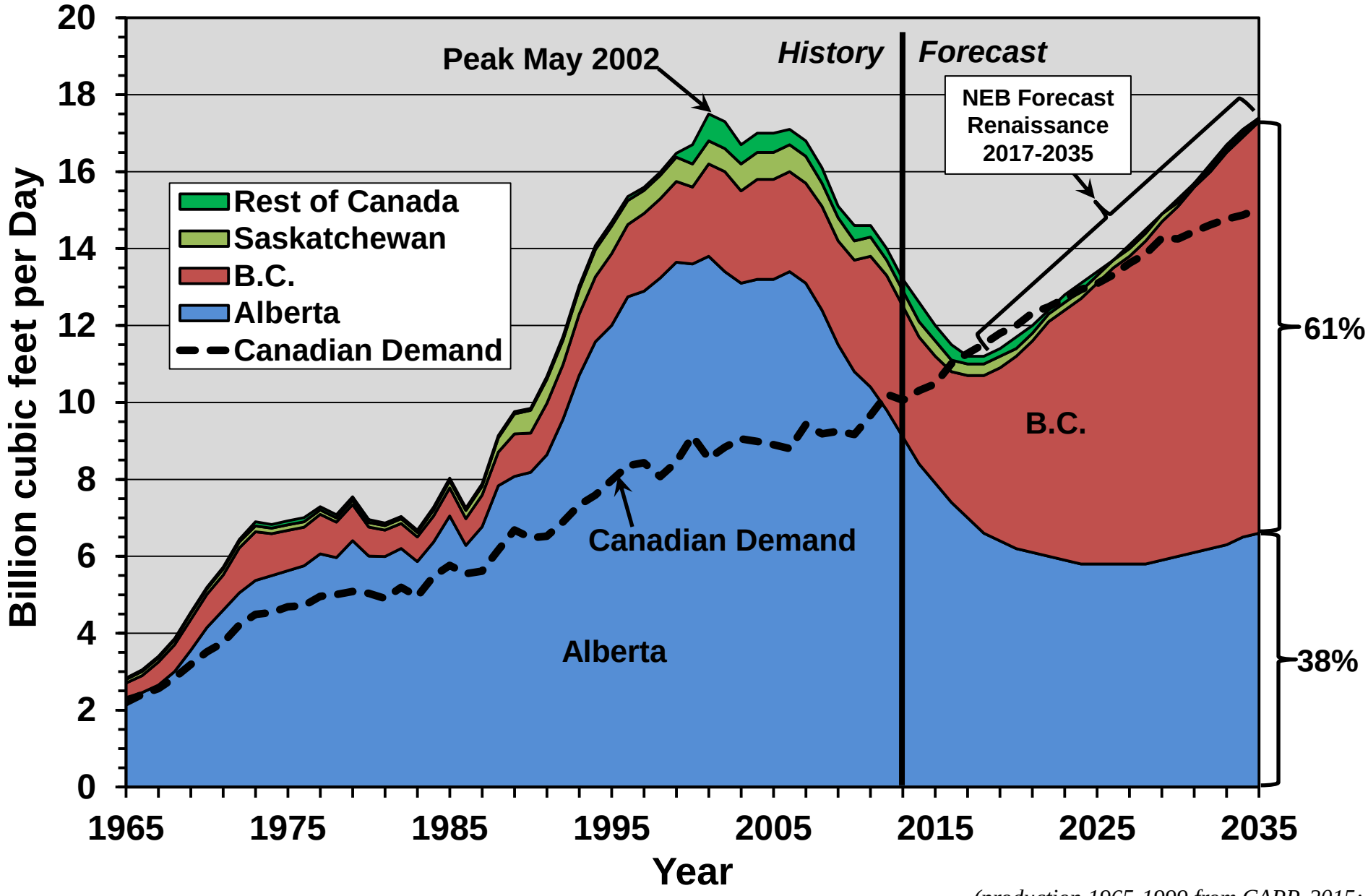
(data from Drillinginfo, February, 2015)

Canadian Gas Production by Province – 2000-2014



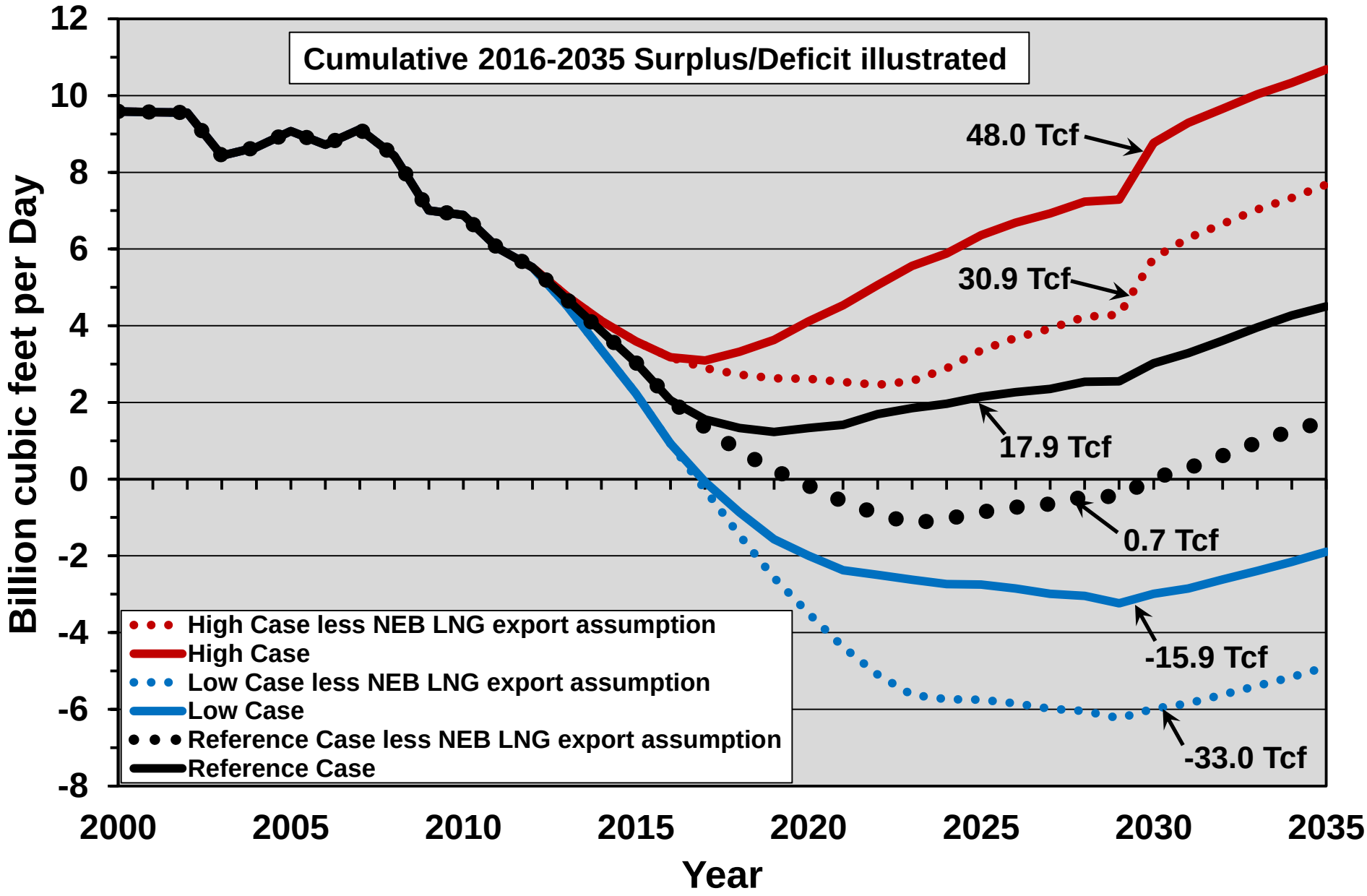
(3-month trailing moving average; data from National Energy Board, 2014,

Gas Production and NEB Forecast by Province – 1965-2035



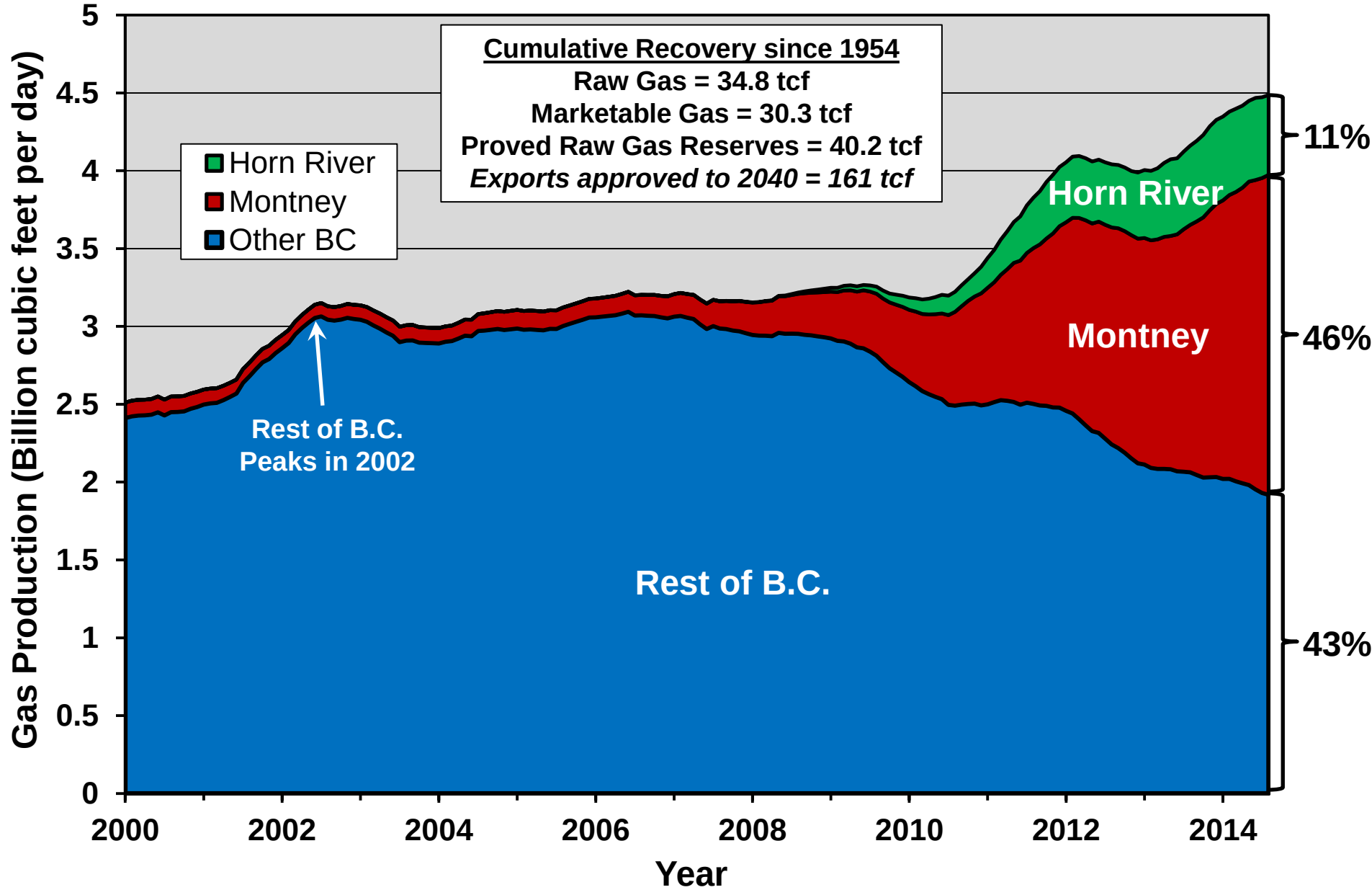
(production 1965-1999 from CAPP, 2015;
Consumption 1965-1999 from BP 2014; 2000-2013 production/consumption and reference forecast from NEB, 2013)

NEB Net Natural Gas for Export, 2000-2035

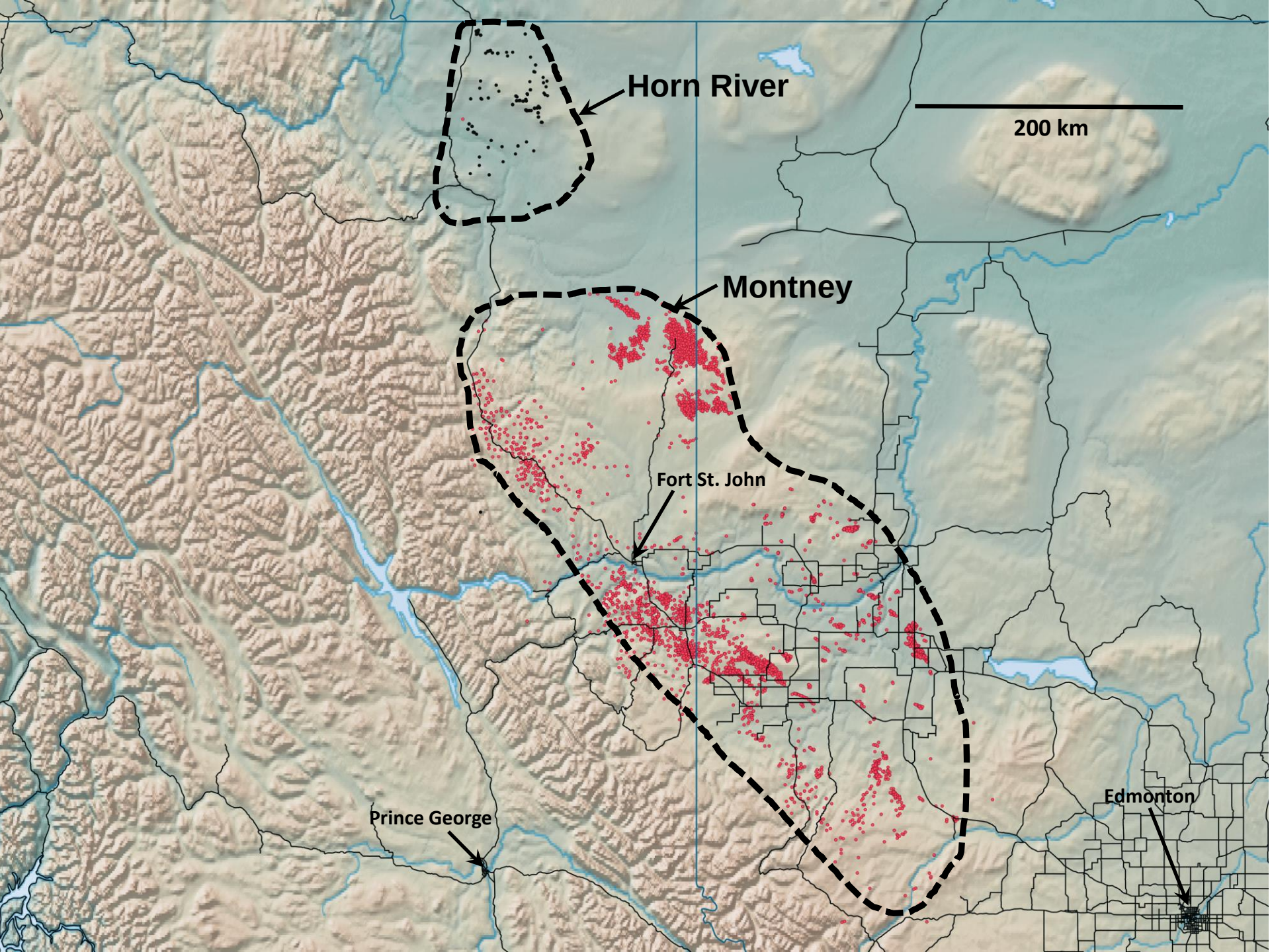


(data from National Energy Board Energy Futures 2013 and NEB personal communication, December, 2014)

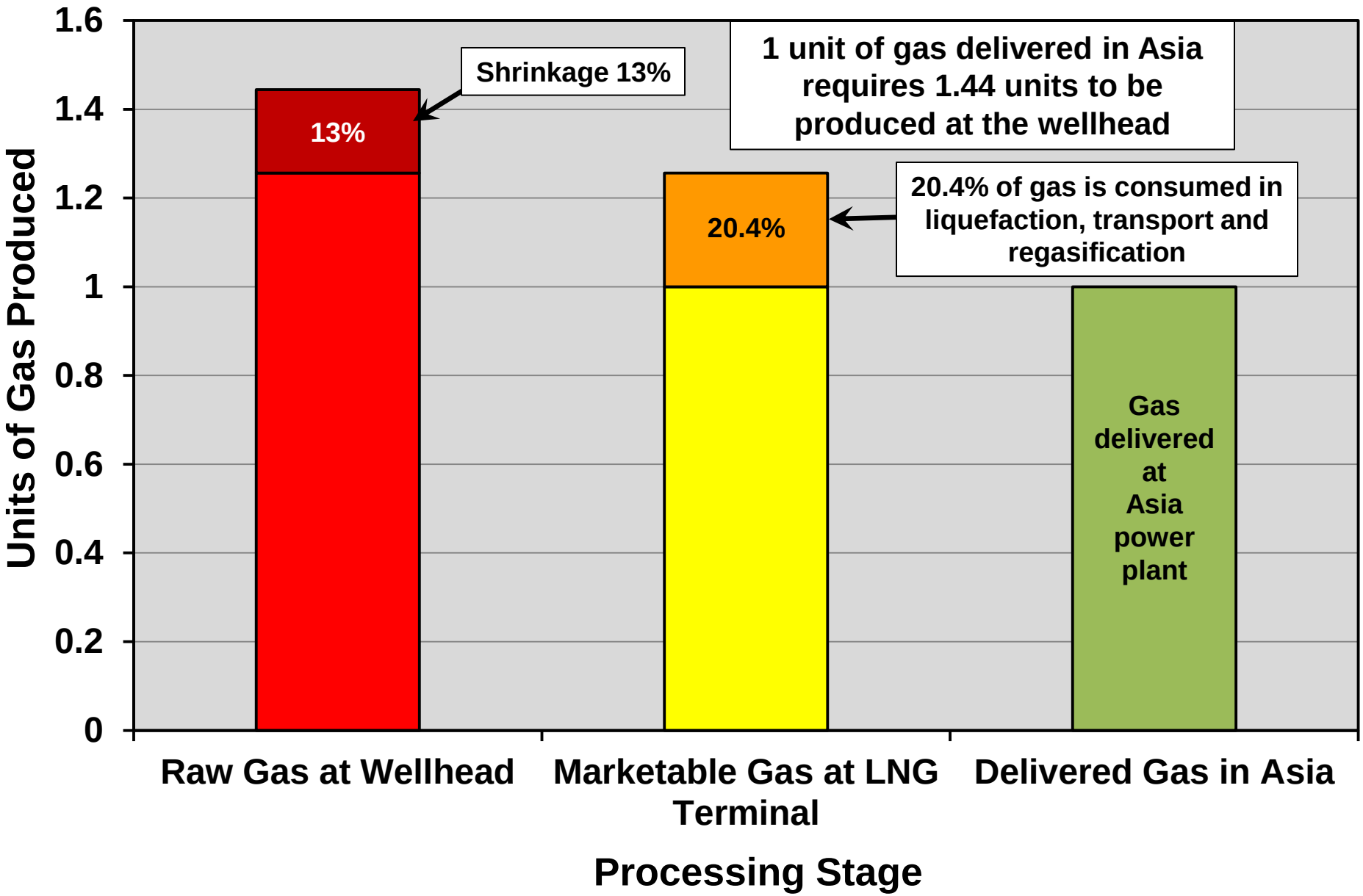
B.C. Raw Gas Production by Play, 2000-2014



 (data from Drillinginfo, December, 2014, for production through August, 2014; twelve month trailing moving average)

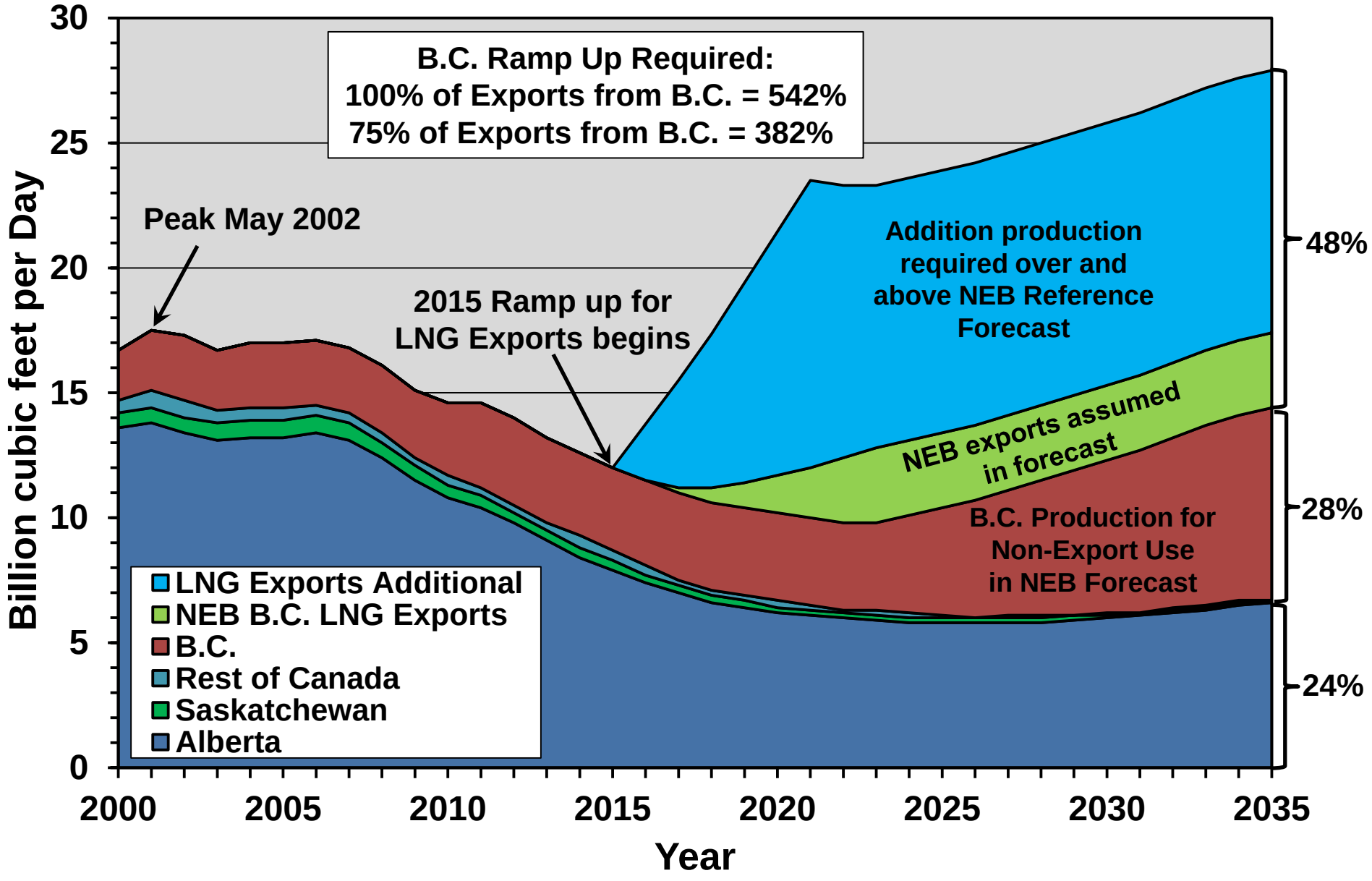

Horn River
Montney
200 km
Fort St. John
Prince George
Edmonton

Wellhead to Power Plant LNG production losses



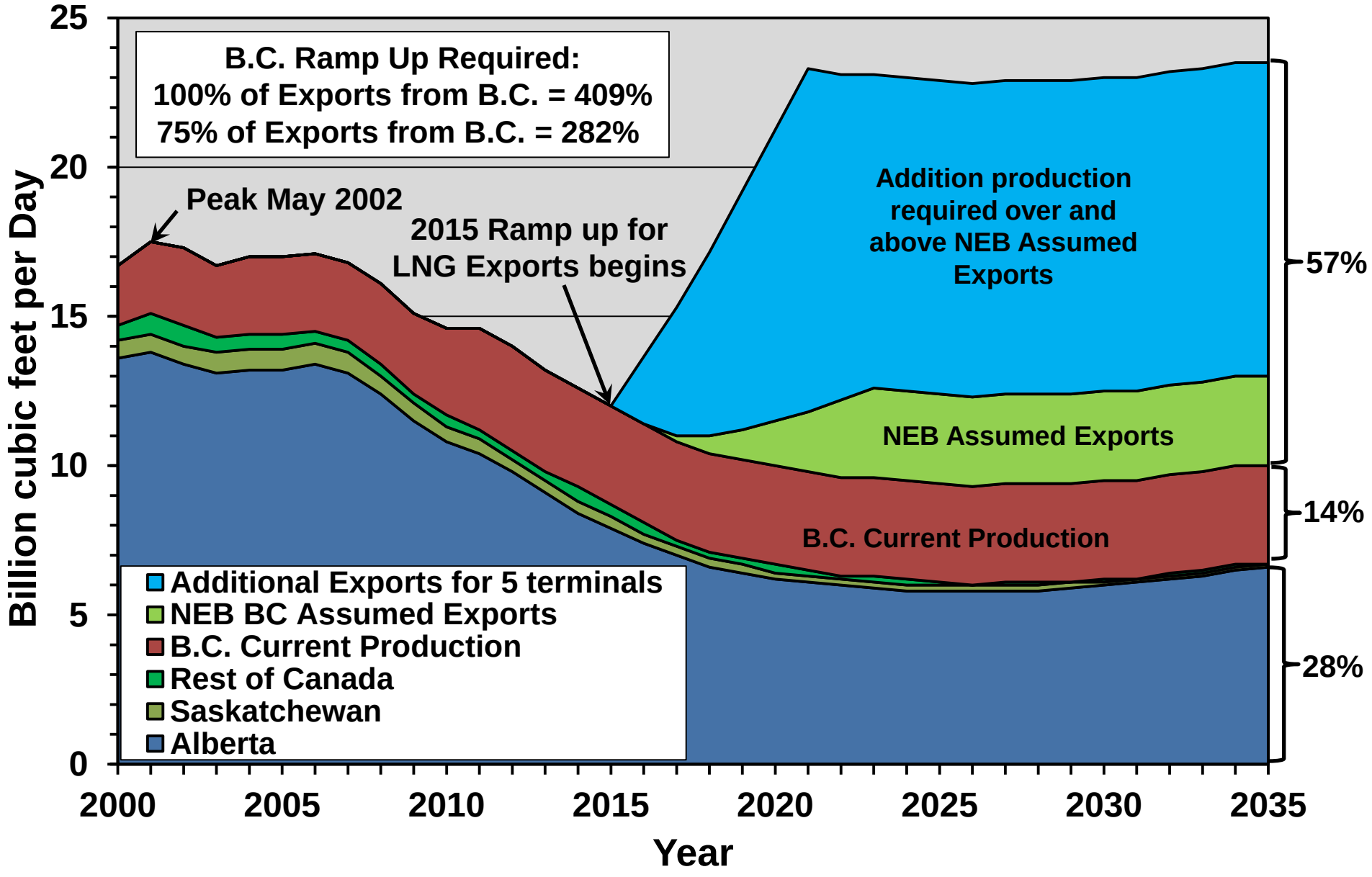
 (B.C. Government LNG in B.C. website; B.C. LNG Alliance; NEB and BC Oil and Gas Commission, 2011, 2012, 2013)

Scenario 1 – LNG exports are incremental to NEB Reference Forecast - 5 terminal Case – 2000-2035



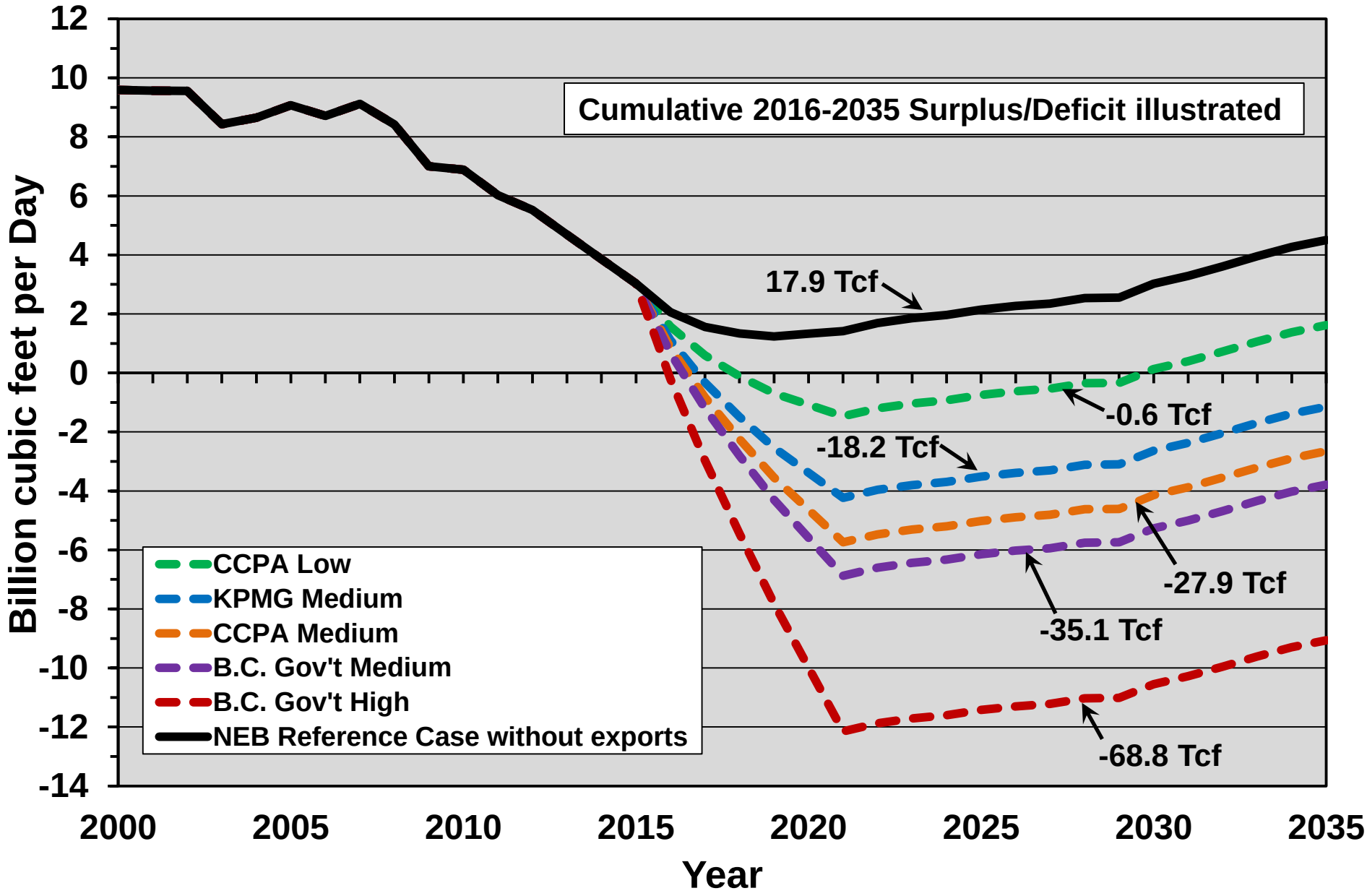
(data from National Energy Board Energy Futures, November, 2013)

Scenario 2 – LNG exports are incremental to Current B.C. Gas Production - 5 terminal Case – 2000-2035



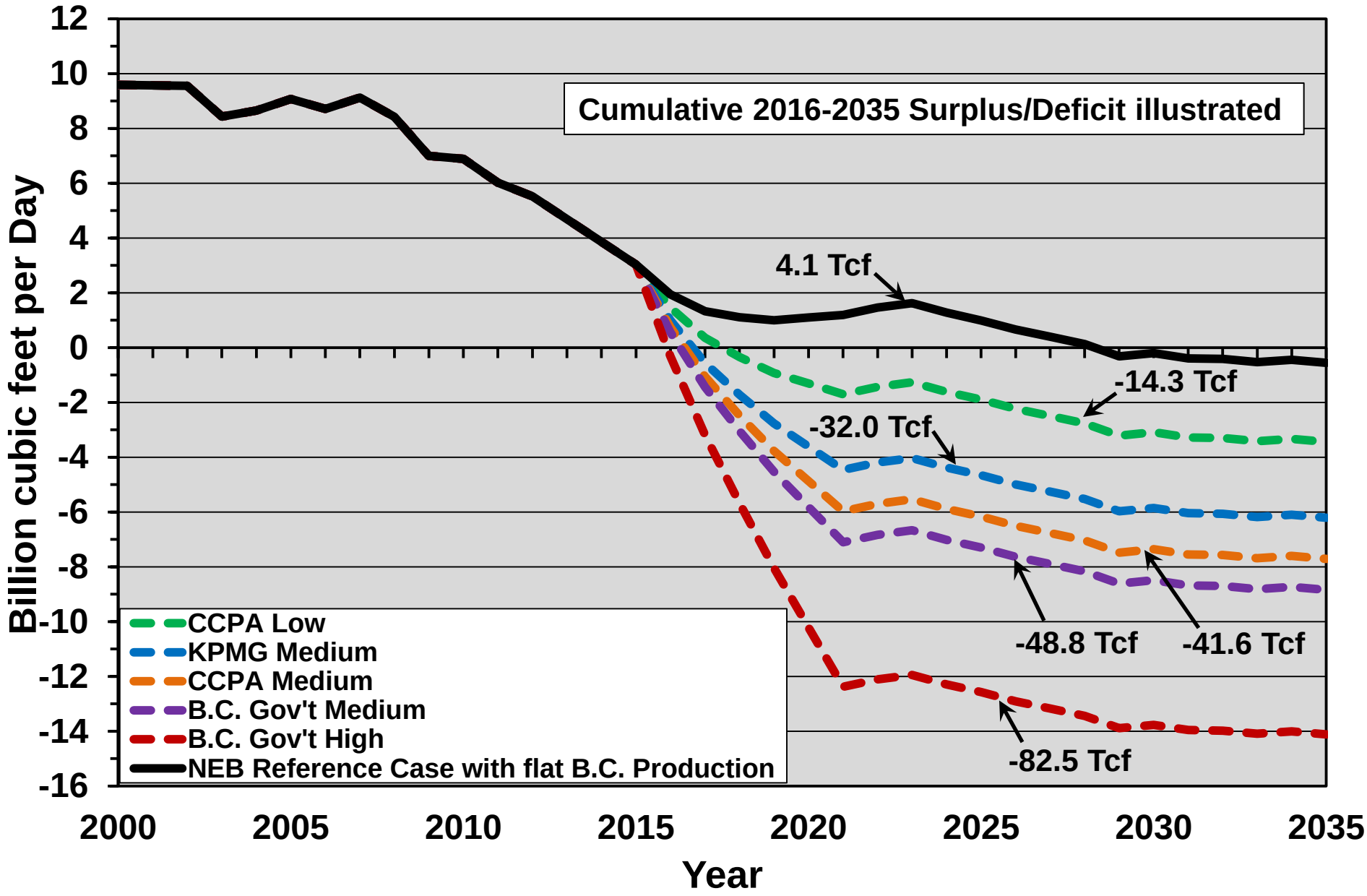
(data from National Energy Board Energy Futures, November, 2013)

Scenario 1 Net Natural Gas Available for Export, 2000-2035



(data from National Energy Board Energy Futures 2013 and NEB personal communication, December, 2014)

Scenario 2 Net Natural Gas Available for Export, 2000-2035



(data from National Energy Board Energy Futures 2013 and NEB personal communication, December, 2014)

Government literature on B.C. Recoverable Gas Resources

GOVERNMENT | FAMILIES & RESIDENTS | DISCOVER B.C. | BUSINESS & INVESTING | HEALTH & SAFETY | EMPLOYMENT | EDUCATION | NEWS

BRITISH COLUMBIA | **LNG in BC**
Liquefied Natural Gas

Services & Forms | News | Contact Us

Search LNG in BC

Learn about LNG | News | Projects | LNG-Buy BC Program | Regional LNG Energy Seminars | LNG in B.C. Conference

CLAIM: 2,933 tcf

LNG in BC – What's the Story?

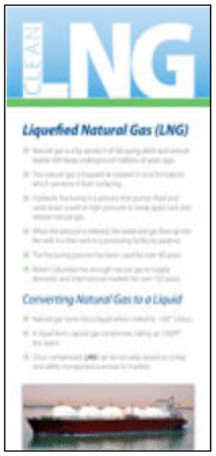
Natural Gas

There is an enormous supply of natural gas in Northeast B.C. – an estimated 2,933 trillion cubic feet – primarily in four key areas: the Horn River Basin, the Montney, the Liard Basin and the Cordova Embayment. This is enough natural gas to support energy needs in Canada and around the world for more than 150 years.

Liquefied Natural Gas

Liquefied Natural Gas (LNG) is natural gas that has been chilled to -160°C. Once

LNG Fact Cards:



LNG

Natural Gas is the World's Cleanest Burning Fossil Fuel

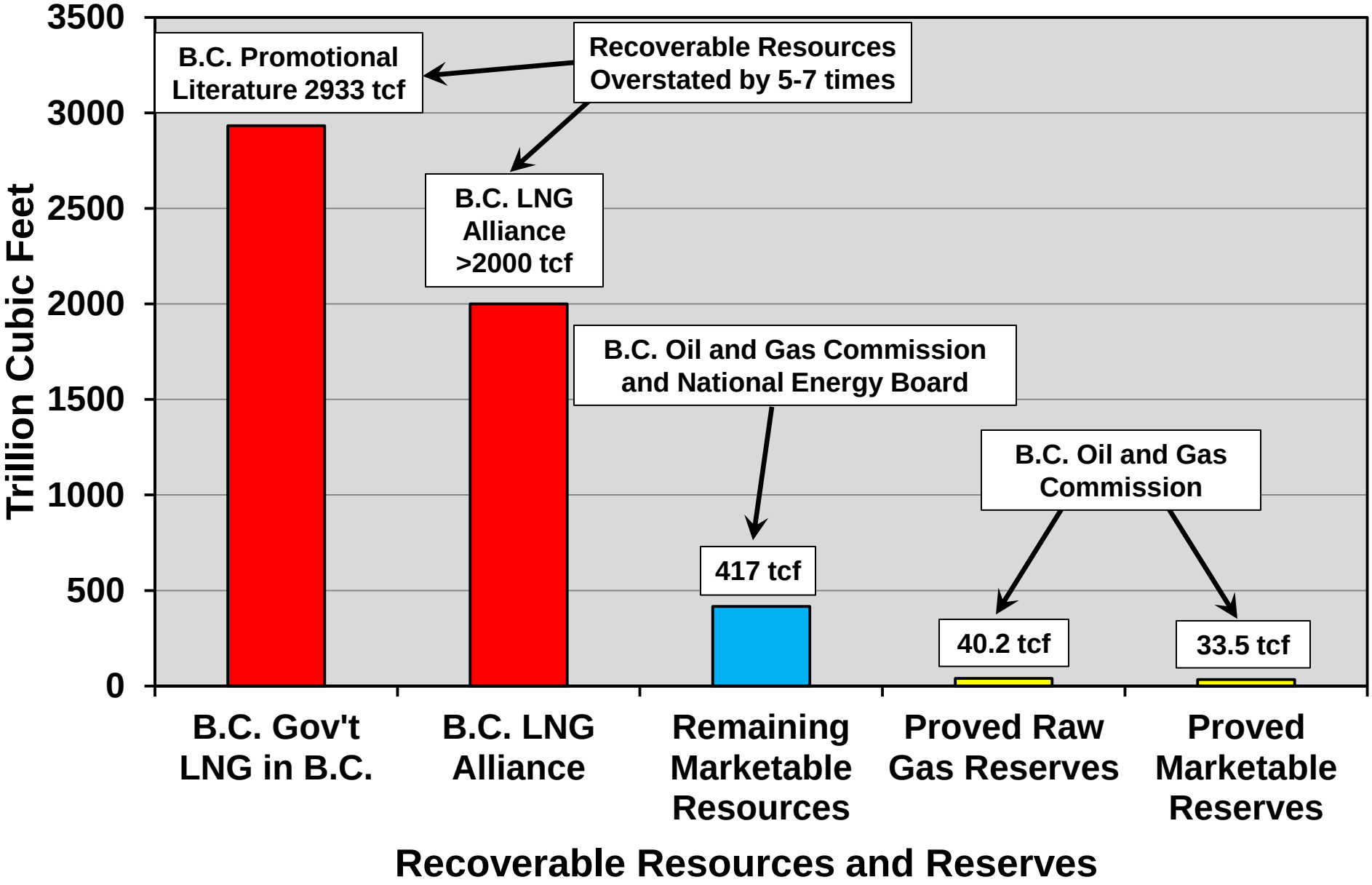
Hydraulic Fracturing

Water

Transportation

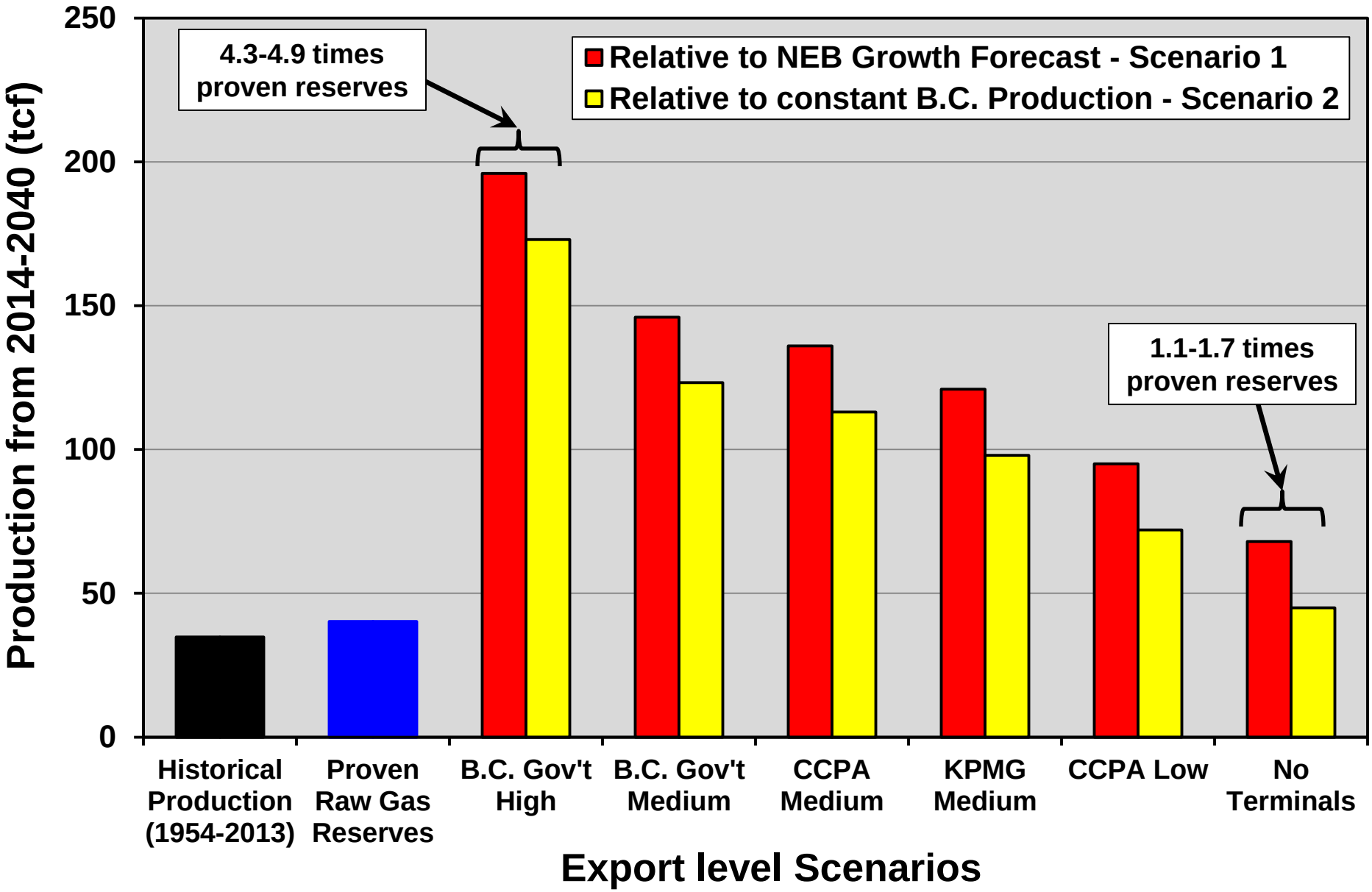
(B.C. Government LNG in B.C. website. retrieved April 10, 2015, http://engage.gov.bc.ca/lnginbc/information-kits/)

Reported Recoverable B.C. Gas Resources and Reserves



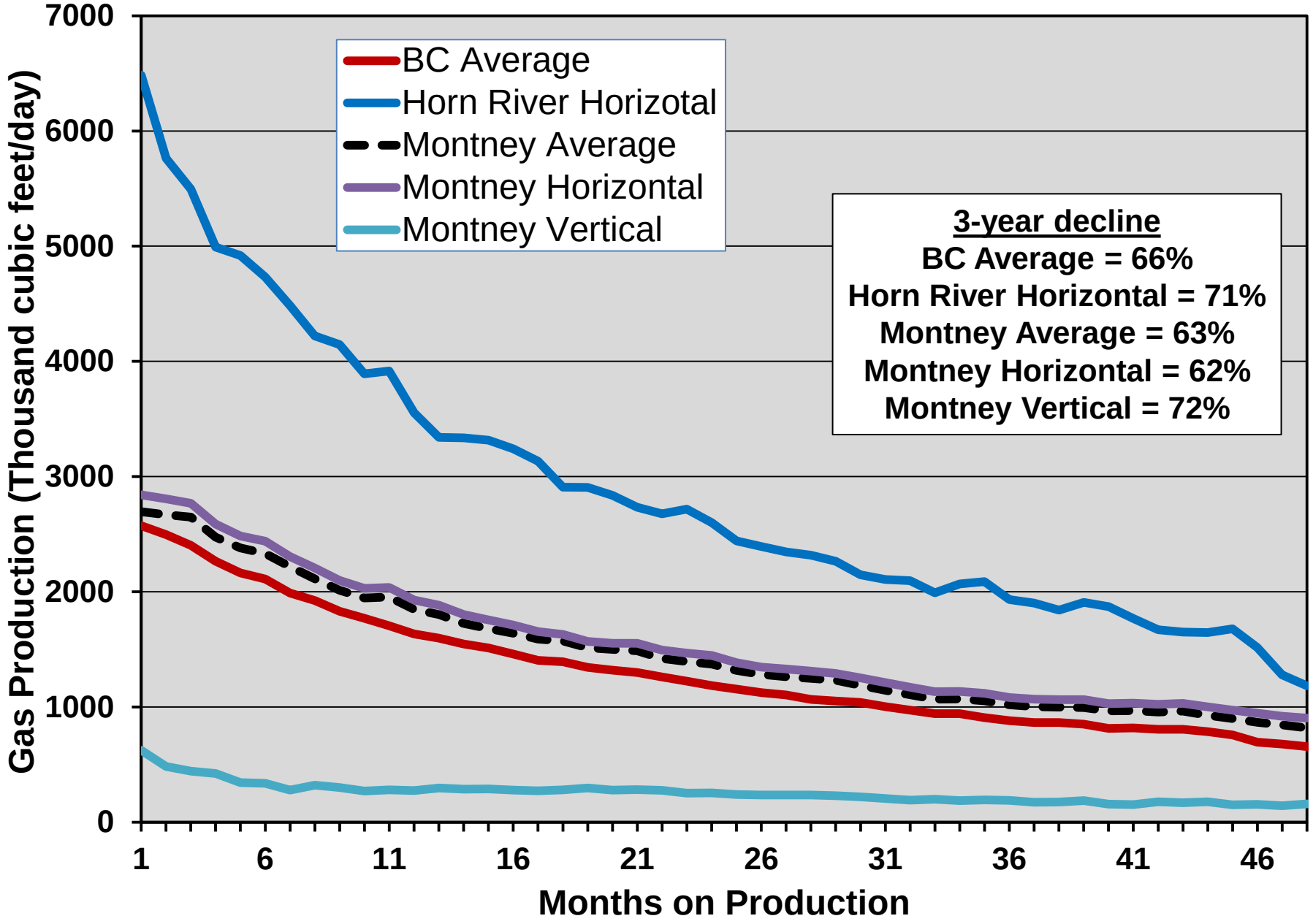
 (B.C. Government LNG in B.C. website; B.C. LNG Alliance; NEB and BC Oil and Gas Commission, 2011, 2012, 2013)

Gas production needed for various LNG export levels from 2014-2040 compared to reserves and past production



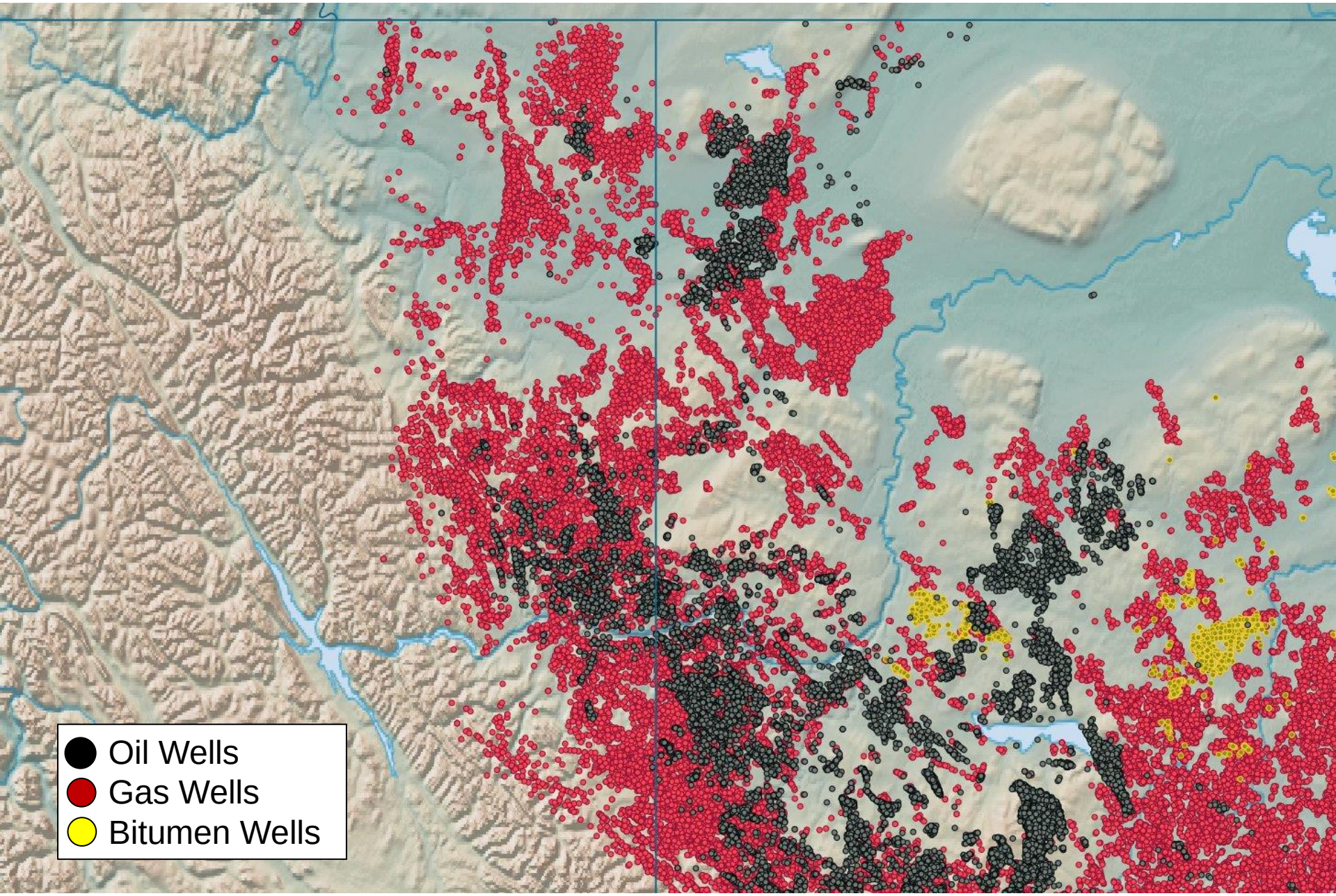
(B.C. LNG Reality Check, 2015)

B.C. Well Decline Curves by Play and Well Type



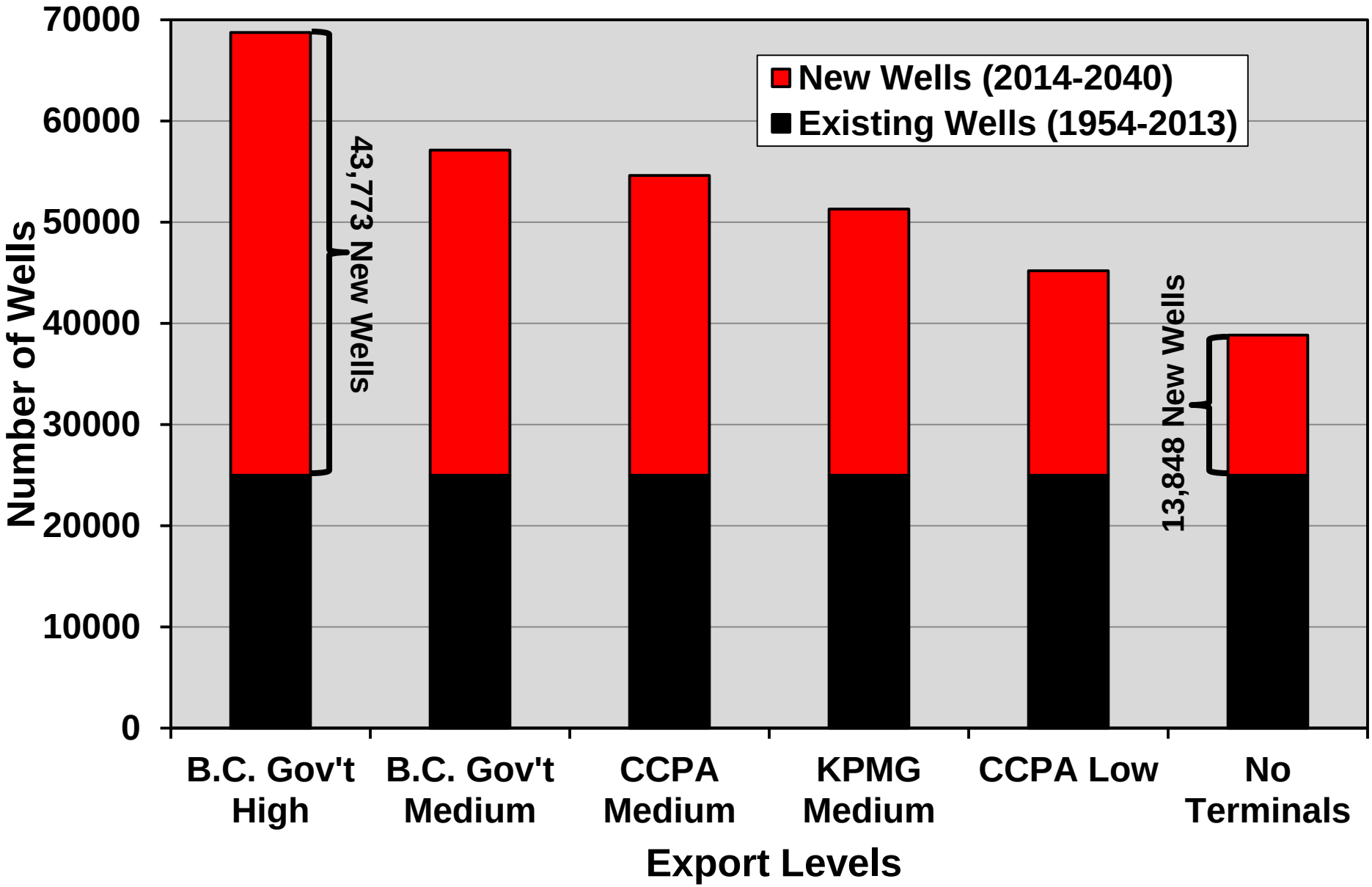
(data from Drillinginfo, April, 2014)

Wells with Current or Historical Production, 1950-2014



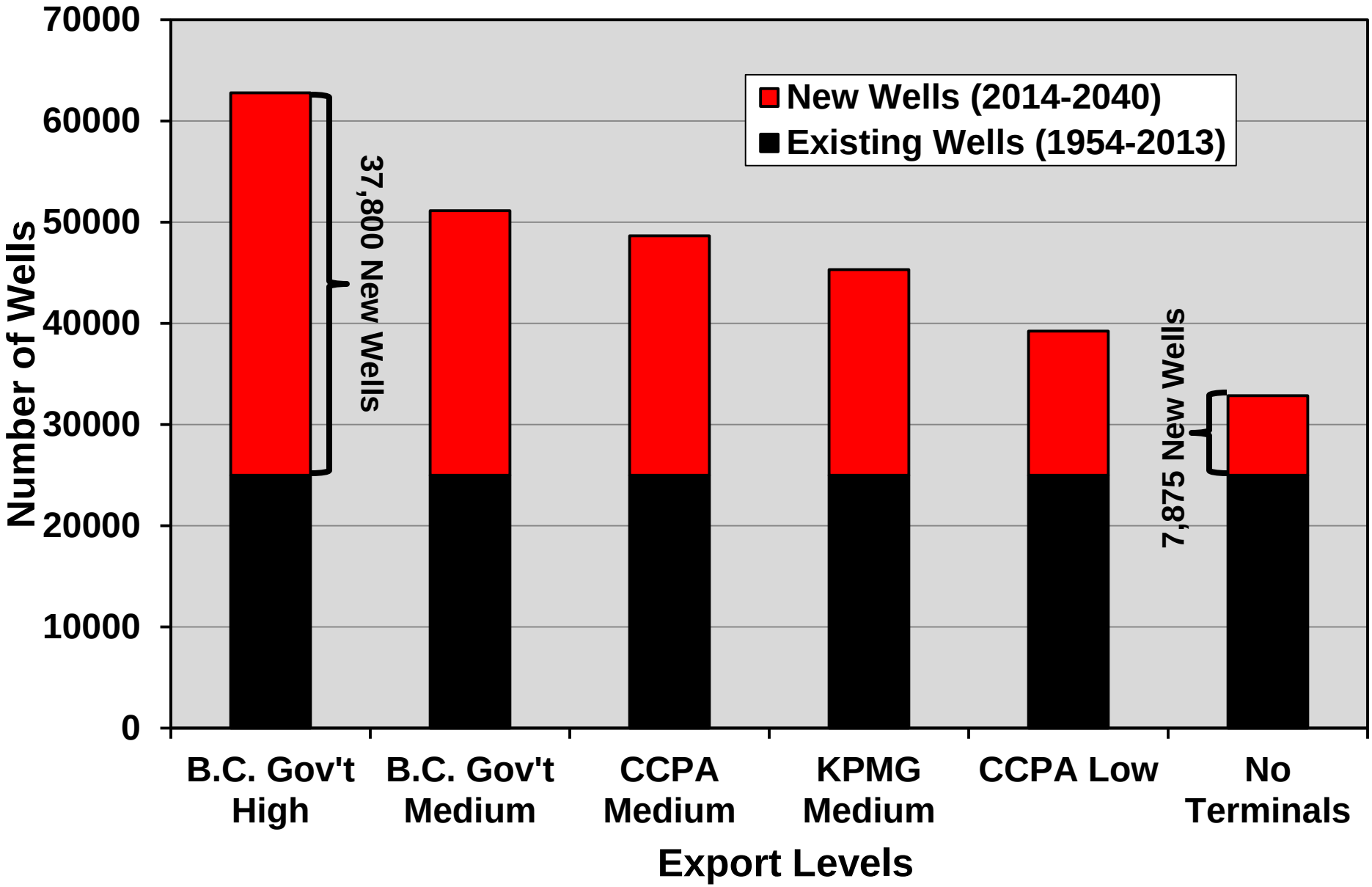
(data from Drillinginfo, February, 2015)

Scenario 1 - Wells needed for various LNG export levels
Relative to NEB reference case production growth



(B.C. LNG Reality Check, 2015)

Scenario 2 - Wells needed for various LNG export levels
Relative to maintaining existing B.C. production



(B.C. LNG Reality Check, 2015)

Environmental Impacts

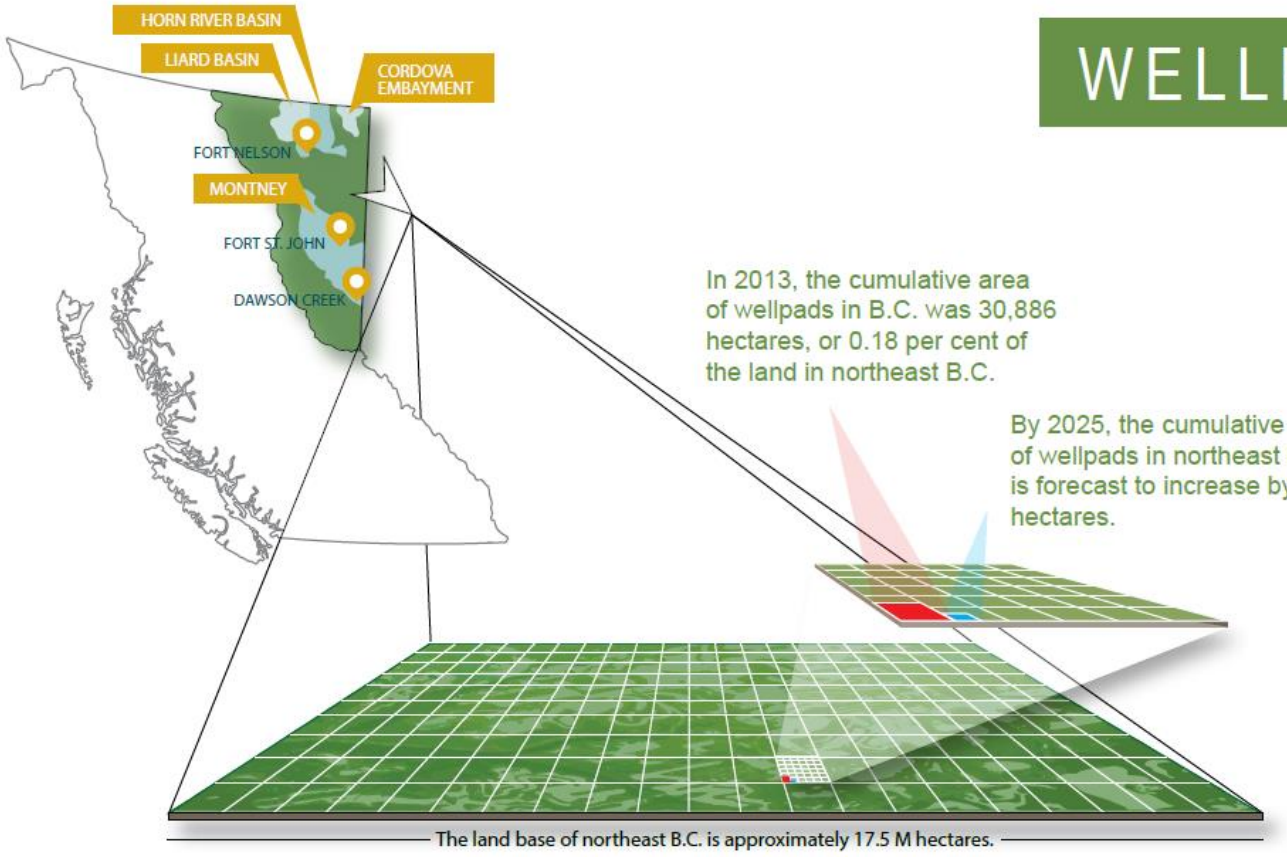
- Land disturbance for LNG terminals and the major pipelines needed to supply them.
- Land disturbance associated with wells, gathering pipelines, roads and seismic activities.
- Water consumption. An average Horn River well uses 25 million U.S. gallons and a Montney well 3.5 million gallons. This compares to an average 5 million gallons for a U.S. shale well.
- Truck traffic - >2,500 truck trips per Horn River well, >400 truck trips per Montney well.
- Greenhouse gas emissions.

Upstream
Land Disturbance Assumptions

- Multi-well pads with ten wells per pad.
- 4 hectares per well pad.
- 3 kilometres of roads per pad (20 metre right-of-way).
- 3.5 kilometres of pipelines per pad (18 metre right-of-way)
- No additional disturbance from seismic cut lines – this may be a major underestimate as seismic lines have in the past accounted for 60% of total disturbance.

(per email from B.C. Oil and Gas Commission, 2014; B.C. Oil and Gas Commission, 2013)

B.C. Government LNG literature on Land Disturbance, 2014



CLAIM:
50 sq. km. by 2025

ACTUAL:
616-714 sq. km. by 2040 in 5 terminal case (assuming no new seismic activity)

Land used for oil and gas operations totals approximately 2 per cent of northeast B.C.'s 17.5 M hectare land base.

Wellpads for natural gas drilling range from 3.5 to 5 hectares in size, and the Forecast Scenario uses an average of 4 hectares.

POTENTIAL LNG GROWTH

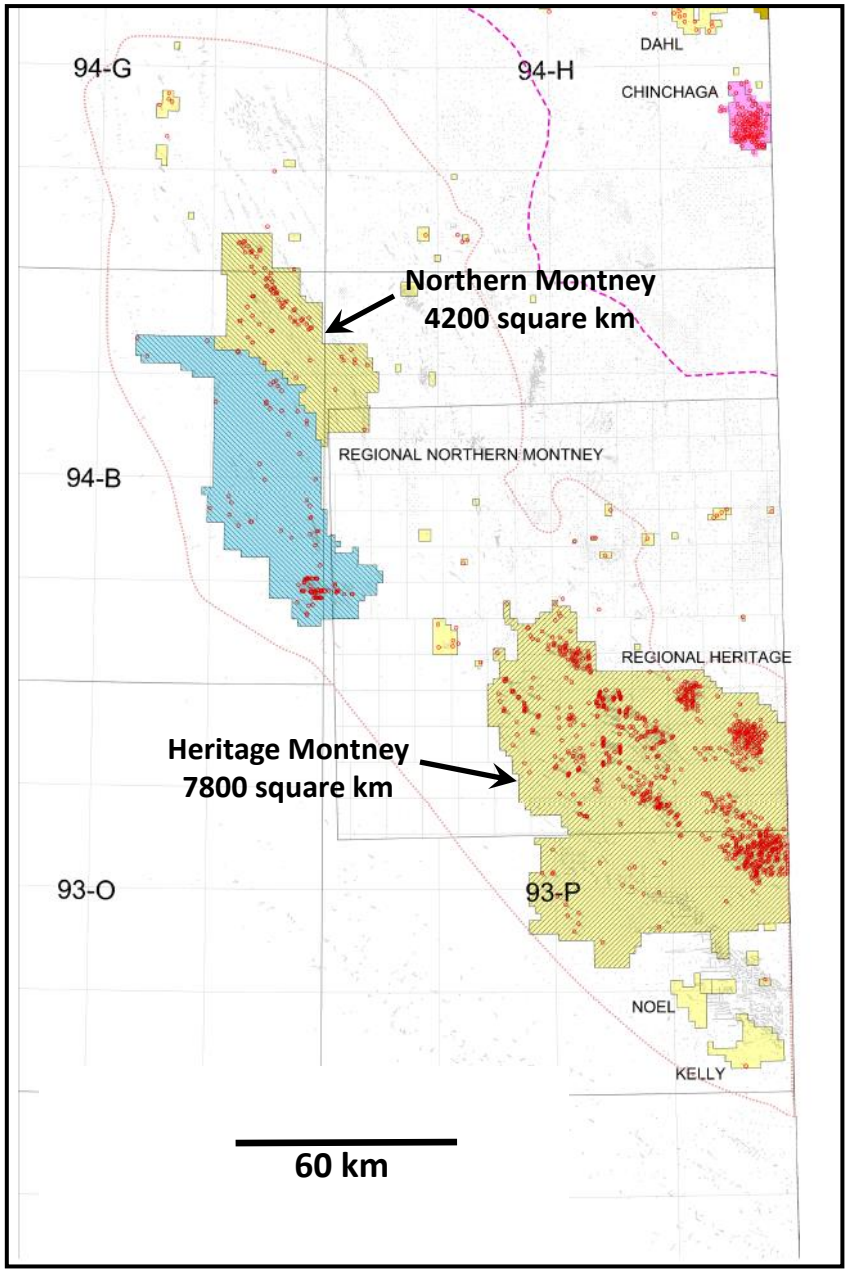
Under the Forecast Scenario, land use for wellpads would increase to 35,911 hectares by 2025.

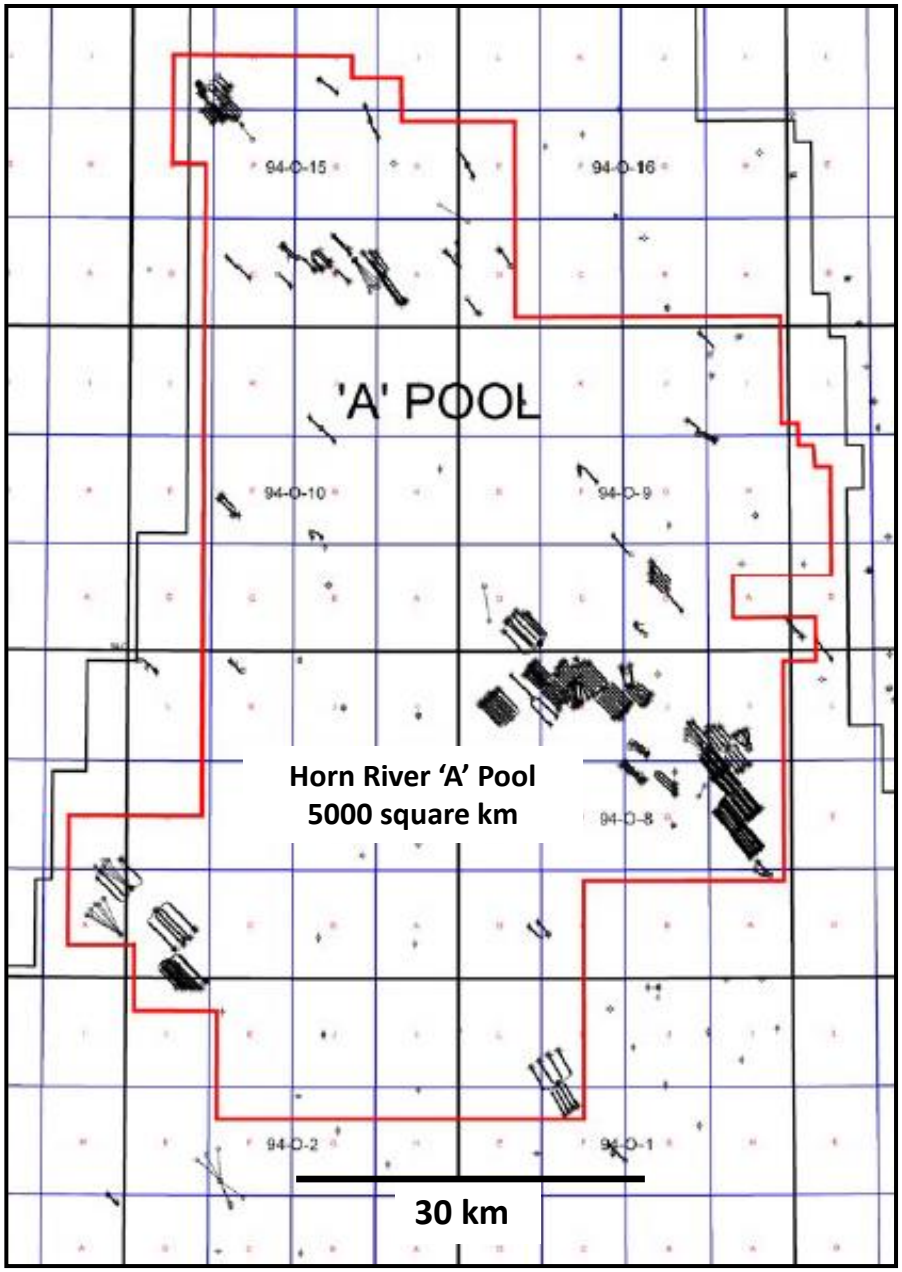
By 2025, wellpads in the Montney are expected to use less than 1 per cent of the land area in that play.

By 2025, wellpads in the Horn River Basin are expected to use 0.2 per cent of the land area in that play.

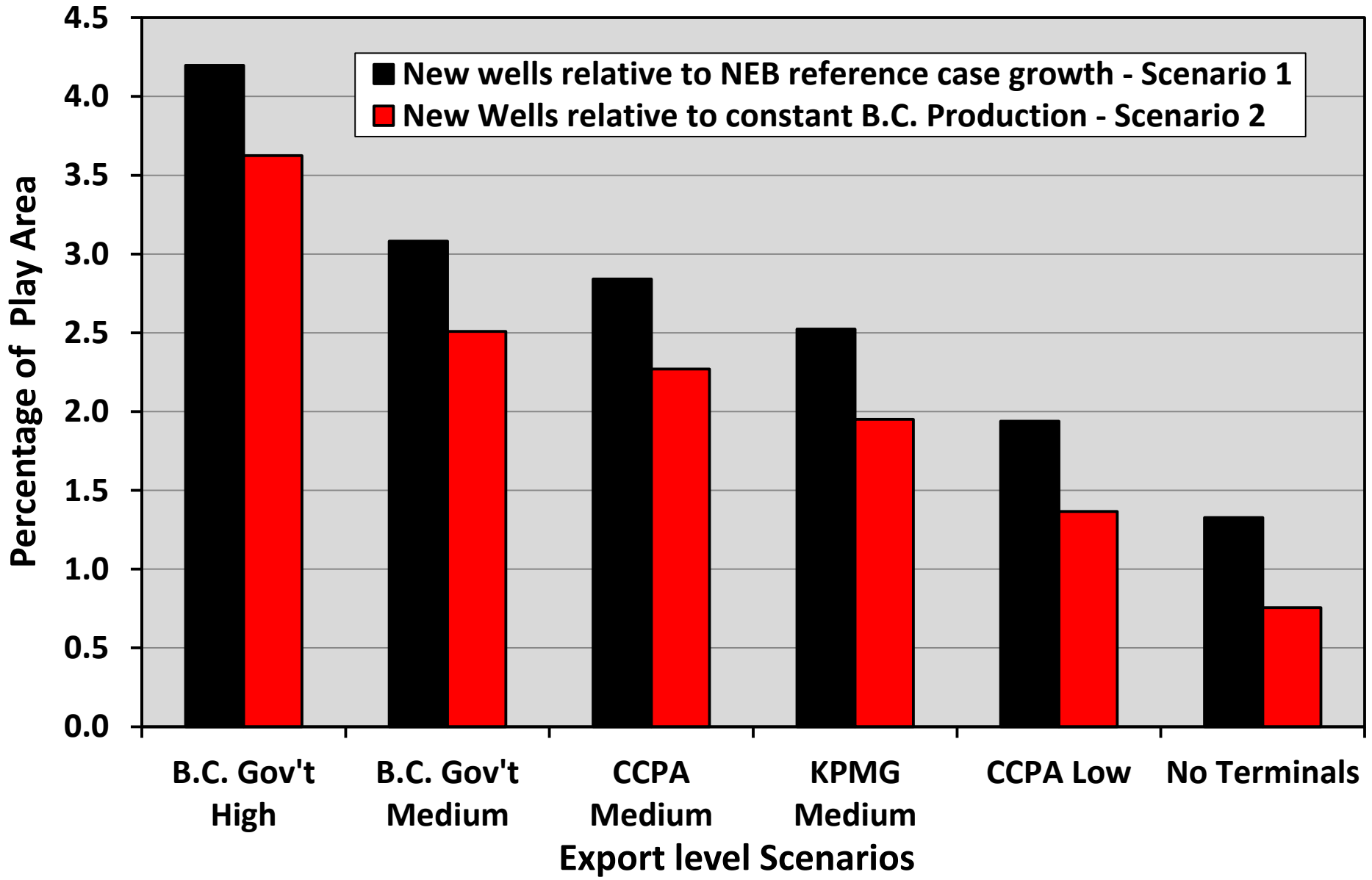
Area-based Analysis

Horn River and Montney Plays – Areal Extent of Main Areas



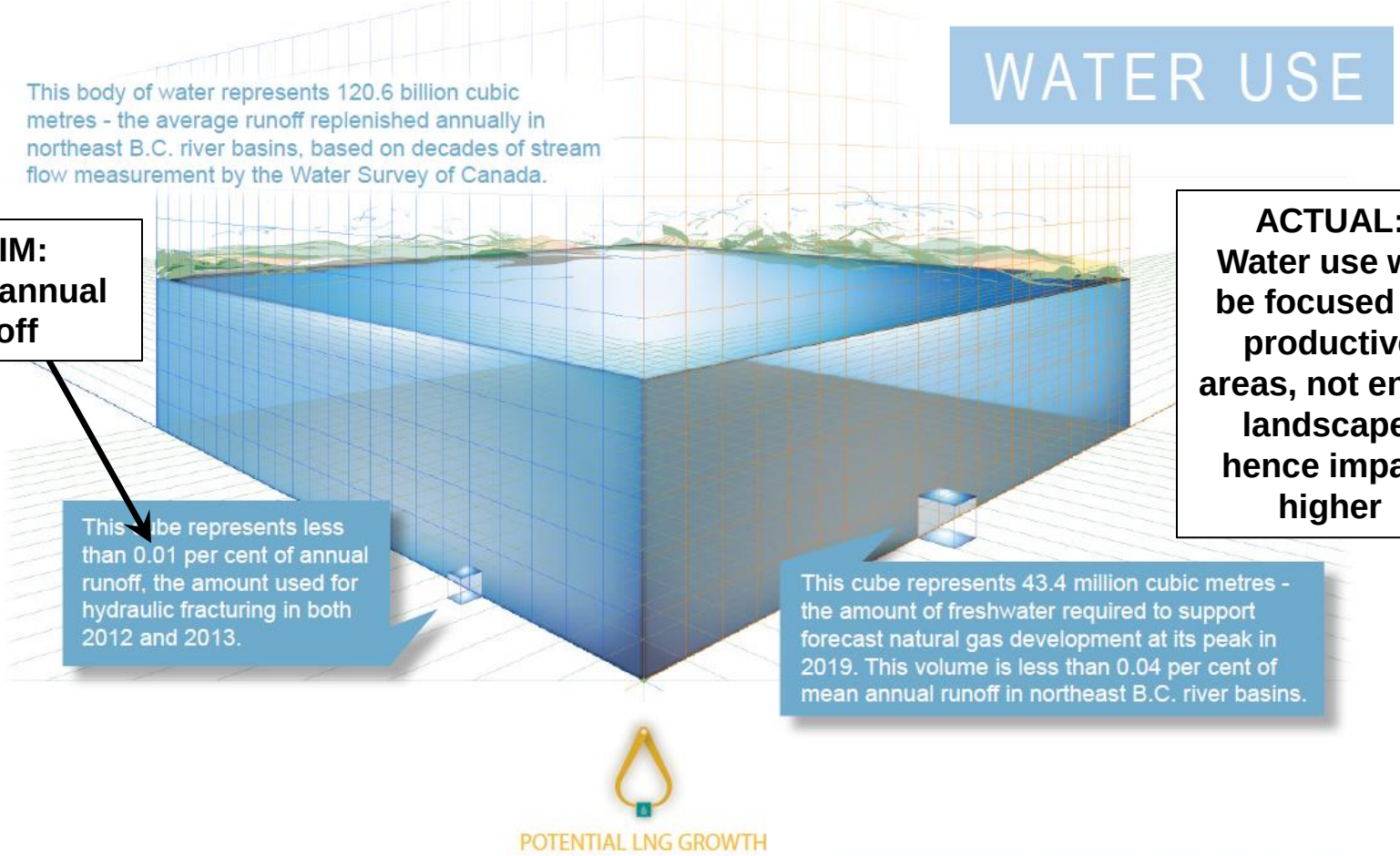


New Land Disturbance in Montney and Horn River Plays in addition to existing land disturbance, 2014-2040



(B.C. LNG Reality Check, 2015)

B.C. Government LNG literature on Water Use, 2014



CLAIM: .01% of annual runoff

ACTUAL: Water use will be focused on productive areas, not entire landscape, hence impact higher

Water is used in natural gas development for a number of reasons including hydraulic fracturing, geophysical exploration and dust control.

READ MORE

Surface water currently accounts for 66 per cent of water used for hydraulic fracturing. The remaining sources include deep aquifer saline water and reused water.

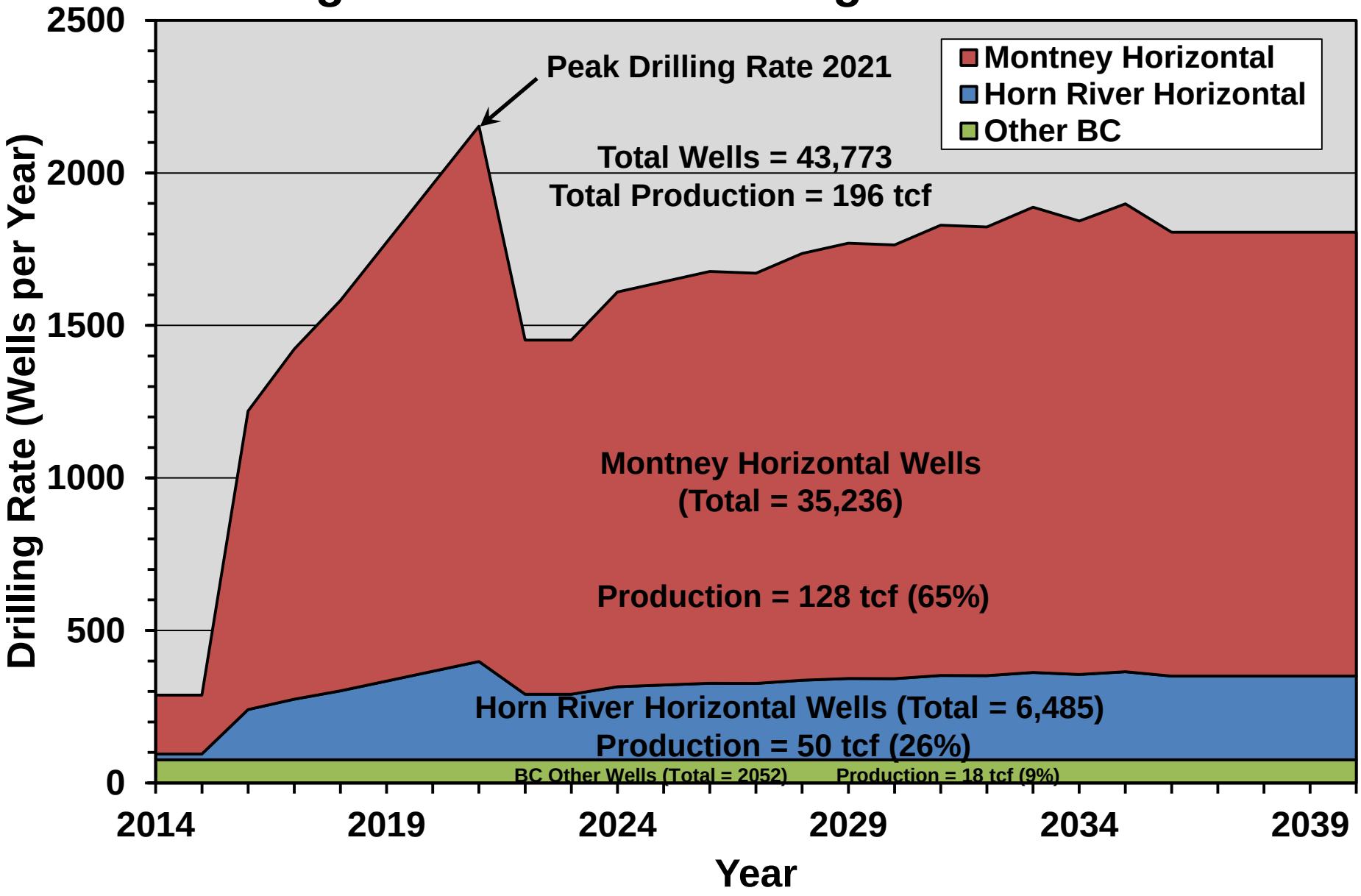
FracFocus.ca

Under the Forecast Scenario, freshwater use for natural gas activities would increase from 2014 to 2019, and decline again through to 2025.

The BC Oil and Gas Commission Water Information page provides access to a wide range of water related data, tools, and reports. This includes the NorthEast Water Tool (NEWT) - a hydrology decision-support tool that provides guidance on water availability in northeast B.C.

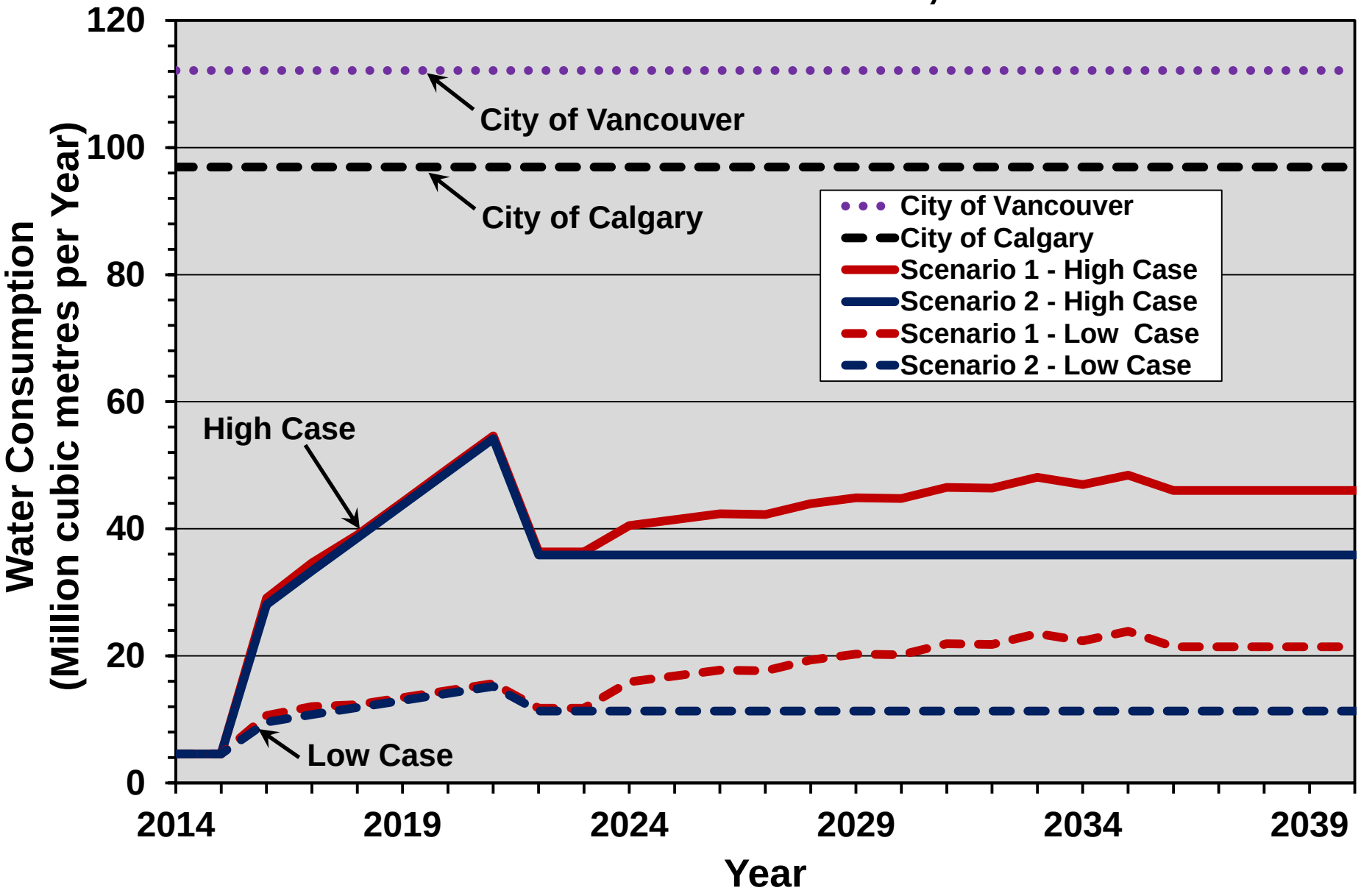
WATER INFORMATION

Drilling Rate with 5 terminal LNG Export - Scenario 1 - assuming NEB reference case growth – 2014-2040



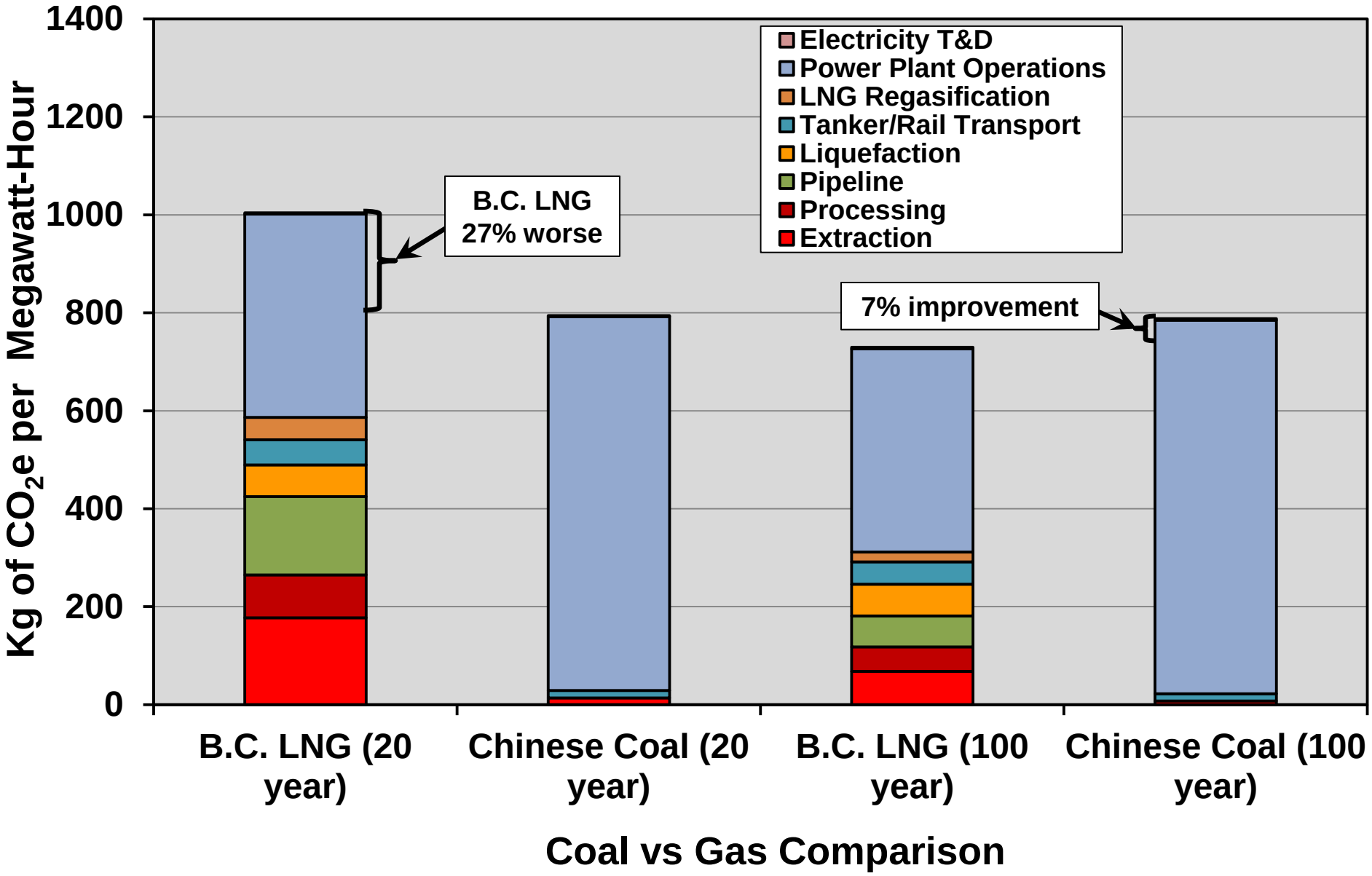
(data from National Energy Board Energy Futures, November, 2013)

Water Consumption for High and Low LNG Export Cases and Two Production Scenarios, 2014-2040



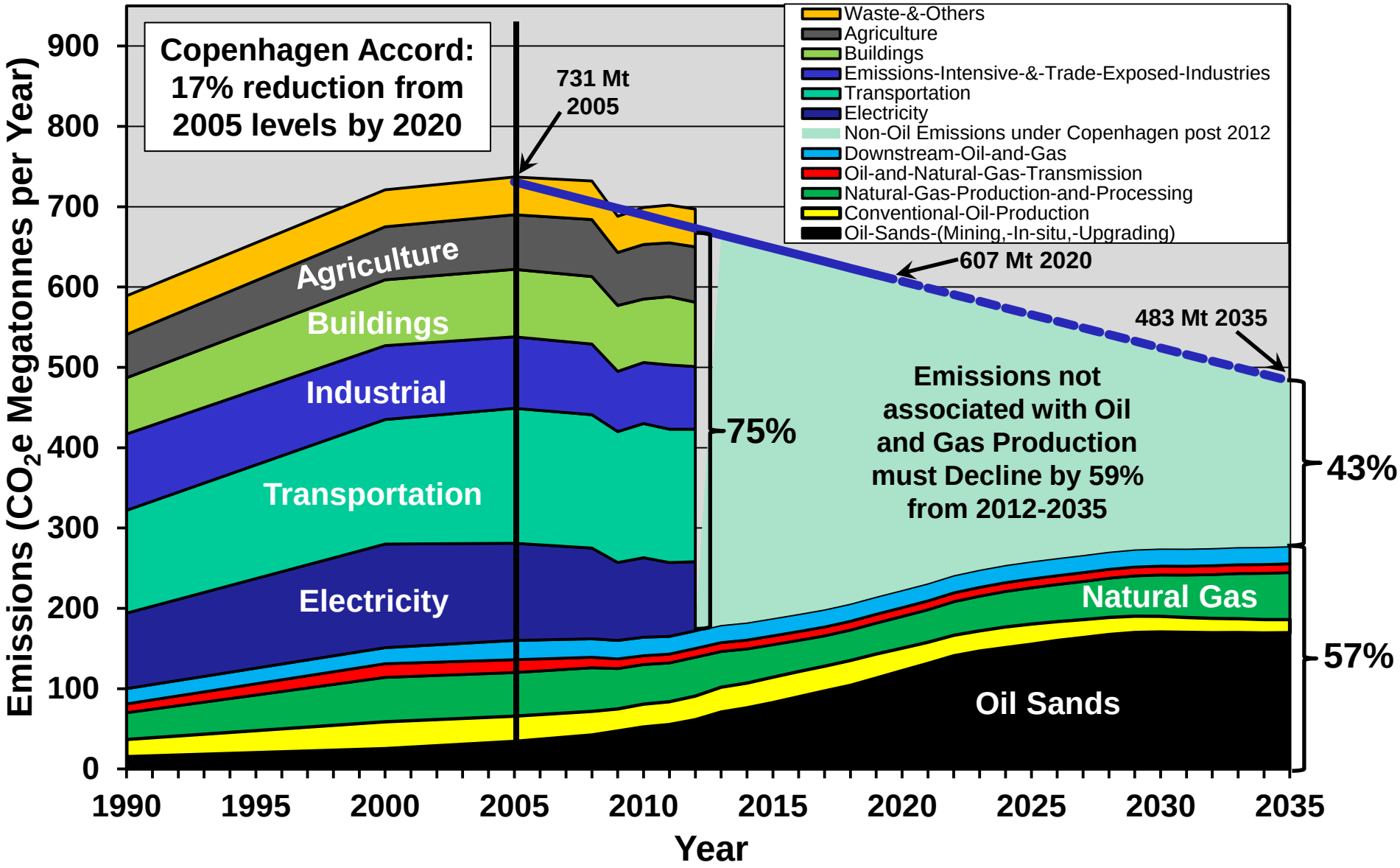
(data from National Energy Board Energy Futures, November, 2013)

Greenhouse Gas Emissions, B.C. LNG versus Best-technology Chinese coal on 20- and 100-year bases



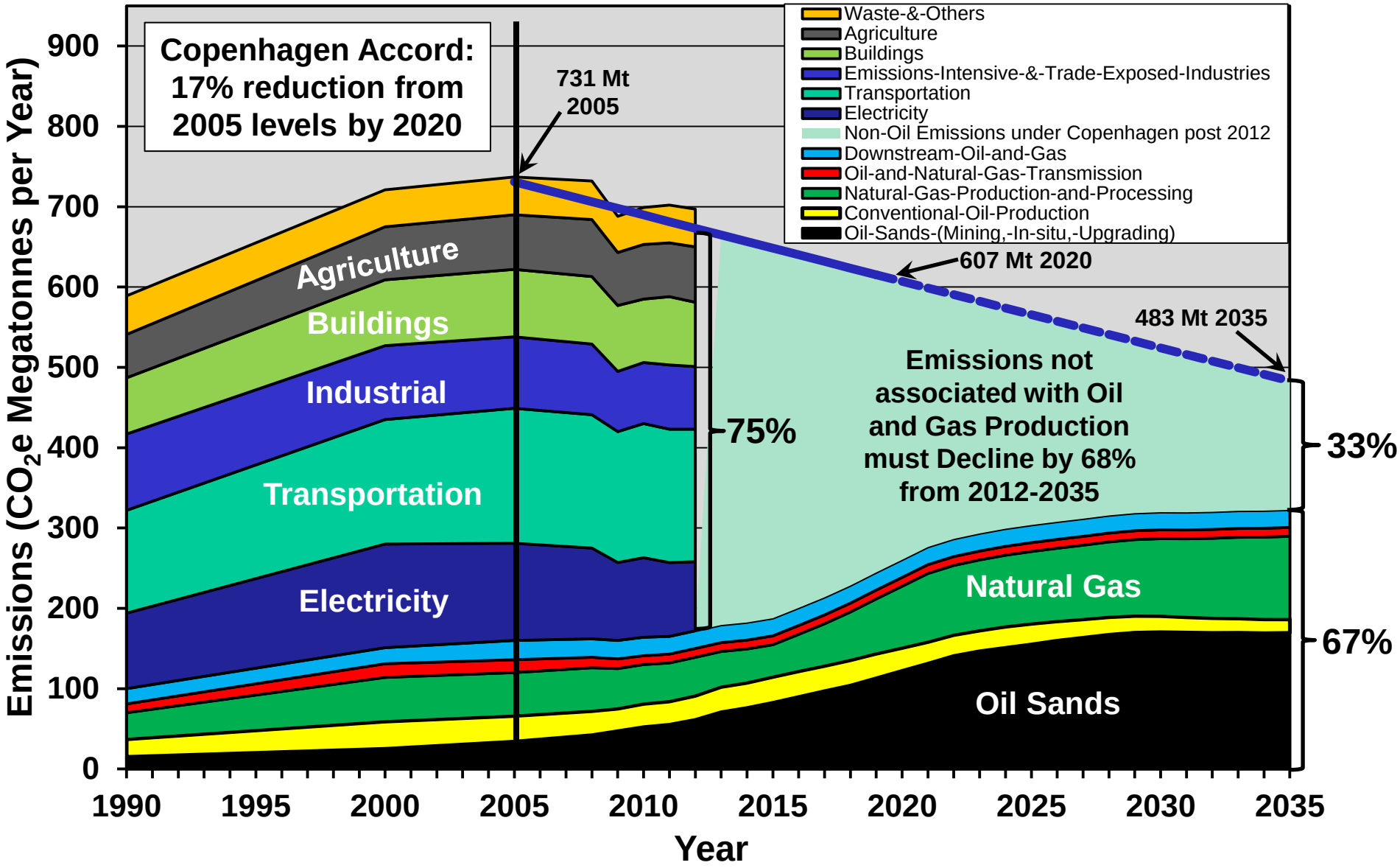
(data from U.S. NETL, 2014; based on 46% efficient ultrasupercritical coal power plants)

Canadian Greenhouse Gas Emissions by Source – History and Forecast under the Copenhagen Accord, 1990-2035



(Environment Canada 2014 National Inventory Report; Forecasts from CERI 2014 and NEB 2013 reference cases; Copenhagen commitments from Environment Canada http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=AD1B22FD-1)

Canadian Greenhouse Gas Emissions by Source – History and Forecast under the Copenhagen Accord with LNG, 1990-2035



(Environment Canada 2014 National Inventory Report; Forecasts from CERI 2014 and NEB 2013 reference cases; Copenhagen commitments from Environment Canada http://www.ec.gc.ca/dd-sd/default.asp?lang=En&n=AD1B22FD-1)

Financial Risks and Considerations

- Viability depends on arbitrage between domestic and Asian gas prices. Asian spot prices have been reduced considerably in recent months.

- High upfront investment requires long term supply and price stability to recover costs. The nature of the shale game with steep decline rates and high cost wells implies price volatility ahead.

- Halving of the LNG tax and increasing write off rates increases the take by corporations and reduces any payment to the owners of the resource, which is non-renewable and comes with impacts.

- Corporations understand these risks very well, hence it is not surprising that there have been no committments to go ahead, even given all the tax breaks and government support.

(per email from B.C. Oil and Gas Commission, 2014; B.C. Oil and Gas Commission, 2013)

U.S. FERC LNG prices April, 2015

(from U.S. FERC website, accessed April 10, 2015)

Summary and Implications

- **Oil and gas are likely to remain an important component of energy consumption for decades, given their energy density and utility for which there are few substitutes.**

- **The “Shale Revolution” has been a “game-changer” but its sustainability in the long term is questionable. This implies higher domestic prices in the future, reducing or eliminating arbitrage for LNG exports.**

- **NEB forecasts are optimistic yet indicate that even if B.C. production more than triples, one LNG terminal would use up all Canadian export capacity. Developing 3-5 terminals would make Canada a major net importer of gas unless production could be ramped up far higher than NEB projections.**

- **The B.C. Government statements of 2,933 trillion cubic feet of recoverable gas resources are contradicted by its own B.C. Oil and Gas Commission and the NEB. They are overstated by 7-fold.**

Summary and Implications

- **The B.C. Government's statements on land disturbance and water consumption downplay impacts as they spread them over the entire northeast of B.C. and look out only to 2025. In fact, the lifespan of an LNG terminal is at least 20 years and the upstream impacts will be concentrated in a small portion of the northeast.**

- **The B.C. Government's claim that LNG will reduce global greenhouse gas emissions considers only emissions at the burner tip, not full-cycle emissions including production, liquefaction and transport. In fact, the world would be better off if China built best-technology coal plants rather than burning B.C. LNG over at least the next 50 years.**

- **The Copenhagen Accord, to which Canada is a signatory, is a modest effort to control GHG emissions and is insufficient according to many. Exporting B.C. LNG at the scale envisioned would make meeting even this target much more difficult, as well as compromise Canada's long term energy security.**

Parting Thought

Canada's *de facto* energy strategy is expediting the liquidation of its finite, non-renewable, resources as quickly as possible in the name of economic development and the government of the day.

These strategic resources are one-time and likely will be needed domestically in the future. They come with collateral environmental impacts and deserve a longer term plan for the sake of future generations and the environment.

B.C. LNG Reality Check: *Energy Security, Environmental Implications and Economic Potential*

Report to be released in May, 2015, by the Canada Centre for Policy Alternatives