Industrial Wood Pellet Fuel in Pulverized Coal Power Plants

A rational, pragmatic, and easy to implement solution for transitioning toward a zero coal future in Alberta.

Alberta and Saskatchewan's Clean Energy Transition
Compliance Strategies and New Development Opportunities
September 26-27, 2016
Calgary, AB

Presented by William Strauss, PhD
President, FutureMetrics

Introductions: Meet The Team

- Leading global consultant in the wood pellet sector
- Provides information, analysis, operations guidance and strategic advice to many of the world's leading companies in the wood pellet sector

- Major manufacturer of wood pellets produced from sustainably managed working forests for use as a renewable, low-carbon fuel
- Subsidiary of Drax Group, the world leader in industrial-scale biomass technology, logistics and operations

- Global leader in providing engineering services to power stations
- Significant experience and in-house expertise in power plant modifications from coal to co-firing or full conversion to wood pellet fuel

- Global leader in building and modifying power plants
- Significant experience in conversion projects, including EPC roles that include guarantees on both reliability and rating

FutureMetrics

Intelligent Analysis and Strategic Leadership for the Pellet Sector

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Consultants to the World's Leading Companies in the Wood Pellet Sector

Selection of Current and Recent Clients of our Team

Award Winning FutureMetrics Team Members

Dr. William Strauss, President, FutureMetrics

Recipient of the 2012 International Excellence in Bioenergy Award

John Swaan, Senior Associate, FutureMetrics

Recipient of the 2014 International Founders Award

FutureMetrics - Globally Respected Consultants in the Wood Pellet Sector

The reason for all this is….

Alberta is planning to phase out all its coal-fired electricity plants by 2030.

Now the federal government has confirmed it wants other provinces to do the same thing. This is a big turnaround, for sure.

Alberta was never considered a leader when it came to carbon reduction strategies before Premier Rachel Notley and her NDP government were elected just over a year ago.

But now Justin Trudeau's Liberals are using Alberta's climate change action plan as a model for other provinces that still burn coal to produce electricity — namely Saskatchewan, Nova Scotia and New Brunswick — and intend to keep doing so until the 2040s.

Trudeau needs those provinces to drastically reduce their use of coal for firing up electricity generators much sooner than that if the federal government is to reach its stated goal of reducing Canada's greenhouse gas emissions by 30 per cent under 2005 levels by 2030.

He is obviously counting on the notion that if Alberta, formerly known as a "laggard" when it came to climate change policies, is taking steps to eliminate all coal-fired electricity in just under 15 years so can the other provinces.

That's because Alberta is Canada's most coal intense province: it produces more coal pollution than all other Canadian provinces combined.

From the Toronto Star, September 8, 2016, by Gillian Steward

COMMODITIES | Mon Sep 19, 2016 |

Canada will impose nationwide carbon price

Canada will impose a carbon price on provinces that do not adequately regulate emissions by themselves, Environment Minister Catherine McKenna said on Sunday without giving details on how the Liberal government will do so.

Wood pellets can replace coal in large pulverized coal power stations

- Optimization of existing asset
- Flexible, dispatchable generation
- **Low carbon**
- Cost competitive
- Demonstrated at scale in many locations
- **Renewable & sustainable**
- Reliable / same uptime
- High output / no de-rate
- **Lower SOx, NOx, Hg emissions**

Industrial Wood Pellets

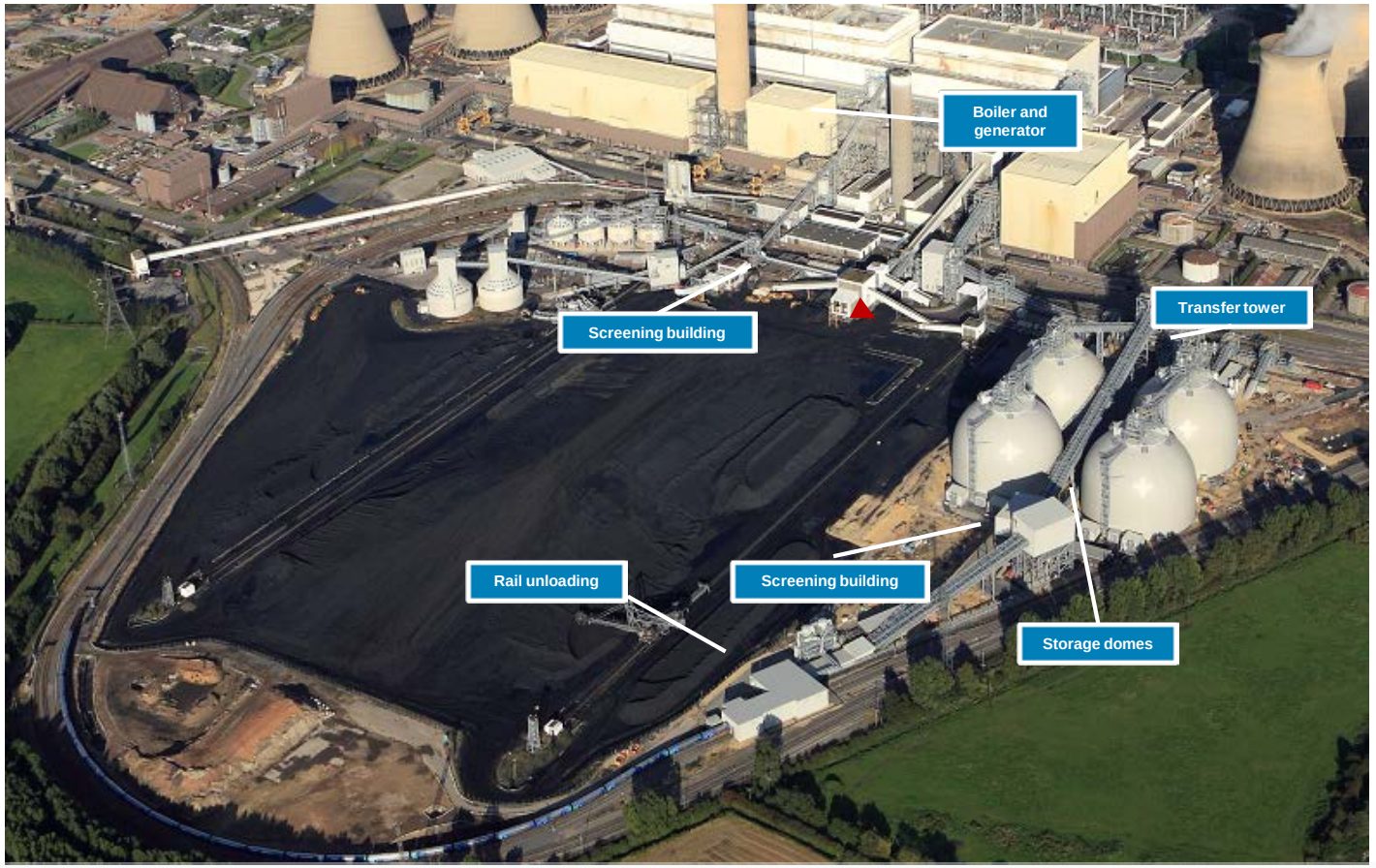
Why Wood Pellets are an Easy Substitute for Coal in Pulverized Coal (PC) Power Plants

- Wood pellets are upgraded solid fuel made from biomass.
- They are grindable.
- They are dry (~6% moisture content).
- They handle easily.
- They have an energy density of ~18 Gigajoules/tonne.

At low co-firing ratios (less than ~6% white wood pellets) no modifications are required.

At higher blend ratios modifications are needed but they are well understood and proven in large PC plants.

Drax Power Station in the UK – Three 645 MW lines: two running on 100% wood pellet fuel and the third on 85% pellets / 15% coal



7.5 million metric tonnes per year of industrial wood pellets

- 3 unit conversion
- Negligible impact on efficiency and no loss of output
- Flexible output from 200MW to 645MW per unit

OPG’s 240 MW Atikokan Ontario Plant

Full firing on industrial wood pellets

Shinchi power station is a 2 x 1,000 MW supercritical coal plant in Japan.

Co-firing at ~3% wood pellets with no mods to the plant.
~160,000 tonnes per year.

Purpose built ship unloader for pellets.

Korea Southeast Power (KOSEP) is co-firing ~5% wood pellets with coal with no modification to the power plant and no dry storage solution at the power plant.

Yeongheung, Korea 5,000 MW Power Station

Pellets are simply metered into the coal before the pulverizers.

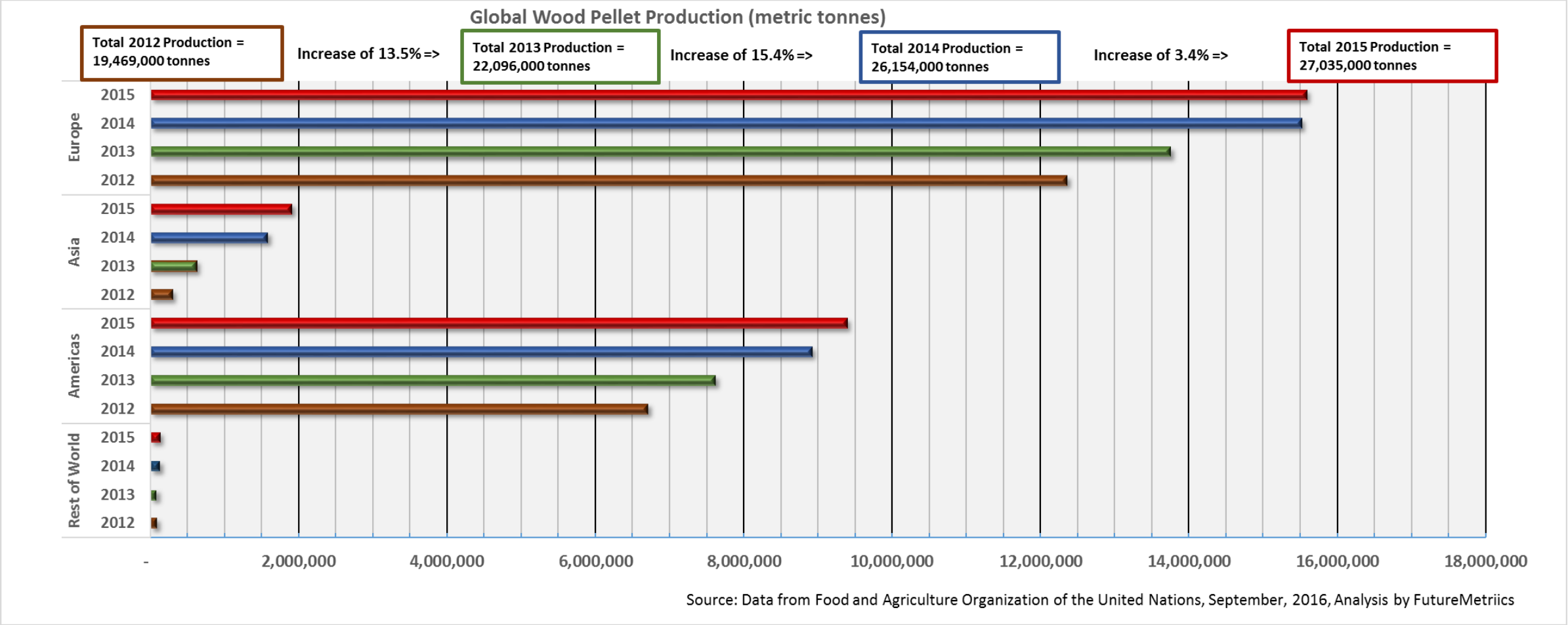
Dong Energy's Avedore Station
Full Firing Wood Pellets – 1.2 million tonnes per year

RWE’s Amer 9 645 MW plant in the Netherlands

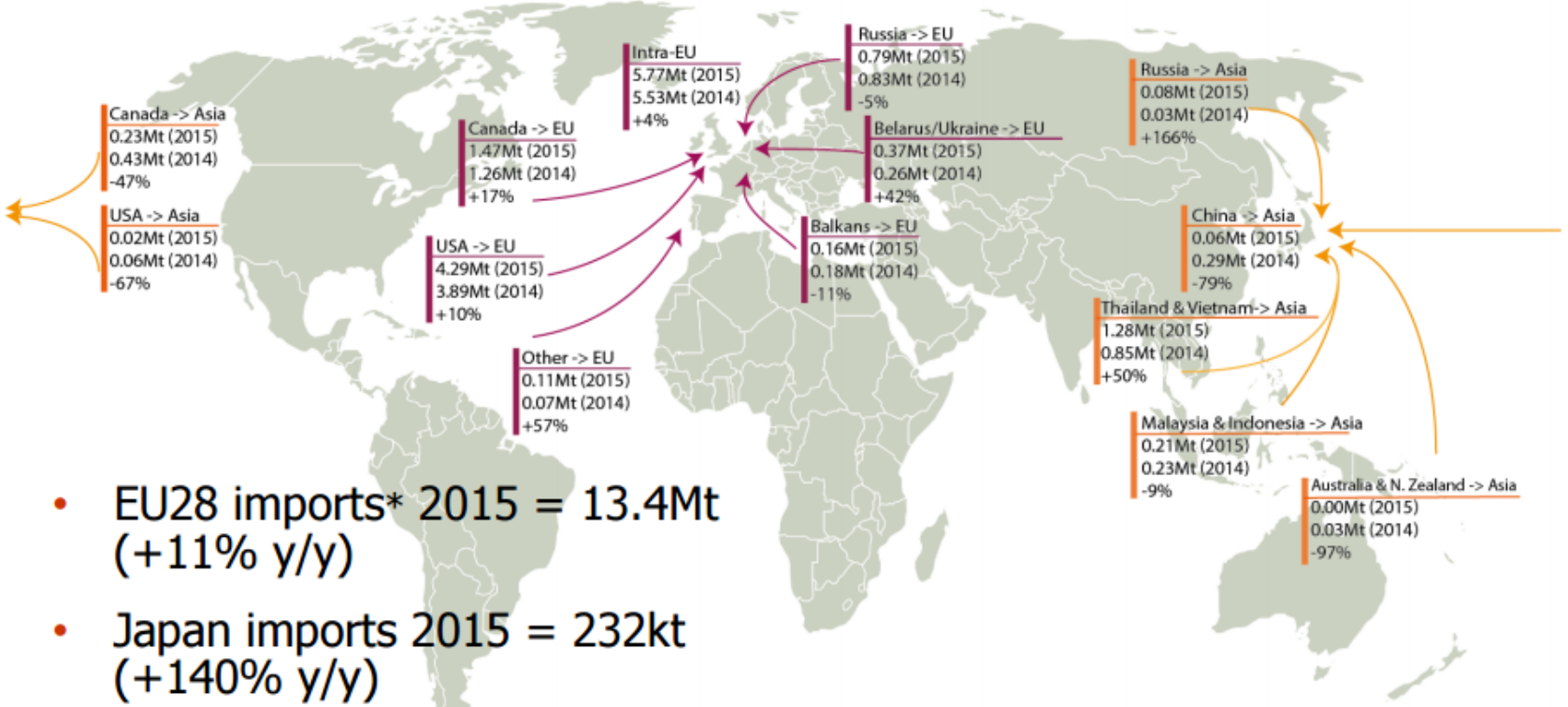
Expected to be co-firing at 50% within the next 6 months

Overview of Global Pellet Markets

Global wood pellet markets have had significant growth in the past decade. The wood pellet market has experienced an annualized growth rate of about 10% from about 19.5 million metric tonnes in 2012 to about 27 million metric tonnes in 2015.



Total Global Wood Pellet Trade – 2014 and 2015 – About 15 million metric tonnes



- EU28 imports* 2015 = 13.4Mt (+11% y/y)
- Japan imports 2015 = 232kt (+140% y/y)
- South Korea imports 2015 = 1.5Mt (-20% y/y)

Sources: Eurostat, Japan & Korea customs data

**Including intra-Europe - not all trade is seaborne*

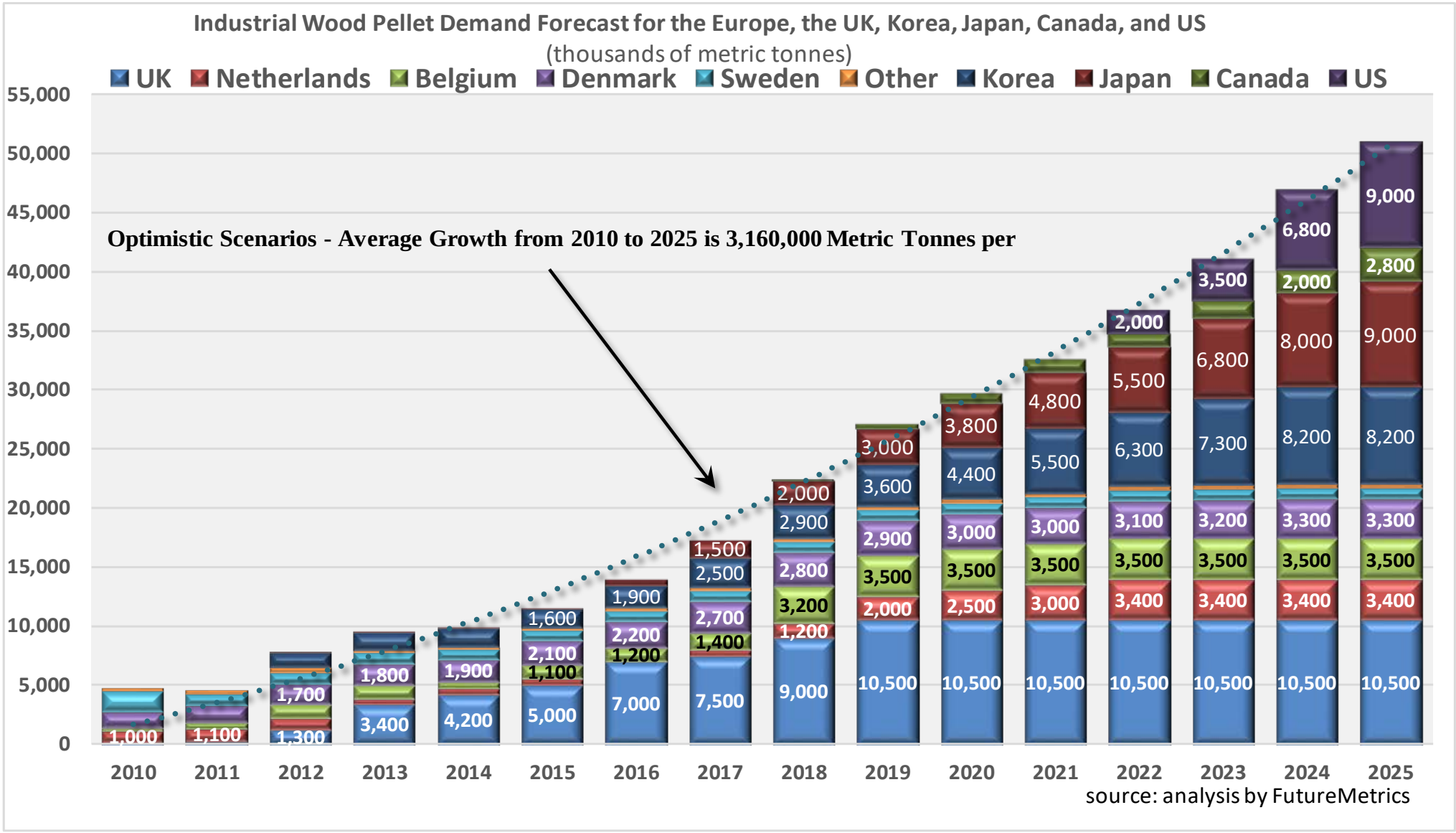
Sources: Eurostat, Japan and Korea customs data, analysis by Hawkins-Wright

The industrial pellet supply chain is robust and is gaining maturity.

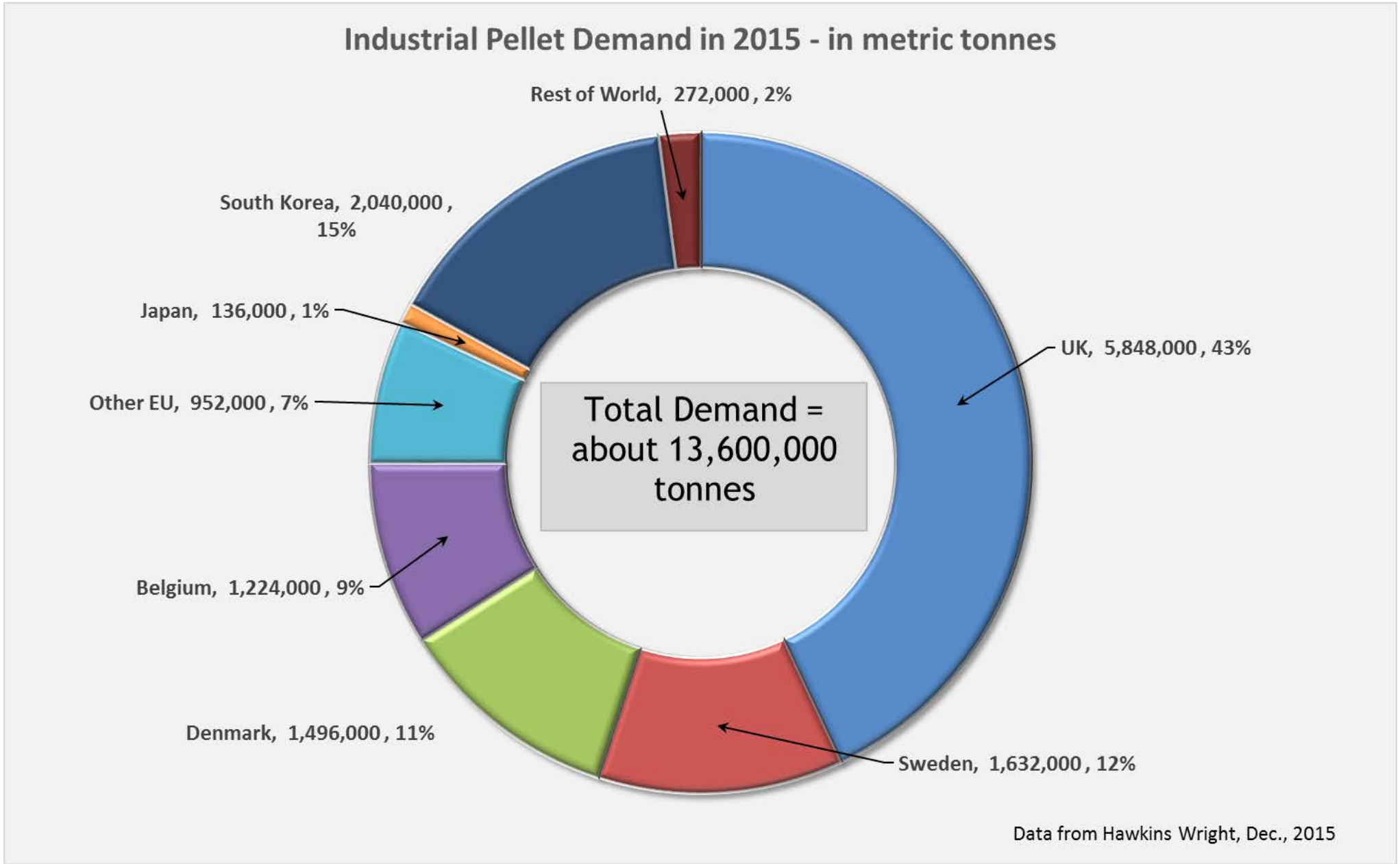
A handymax sized ship (40,000 MT) is loaded with industrial pellets about every 1.5 days.

First ever Panamax shipload of pellets being unloaded on July 15, 2015 in Immingham, UK. Produced in British Columbia by Pinnacle, shipped from their terminal in Prince Rupert, destined for the Drax power station.

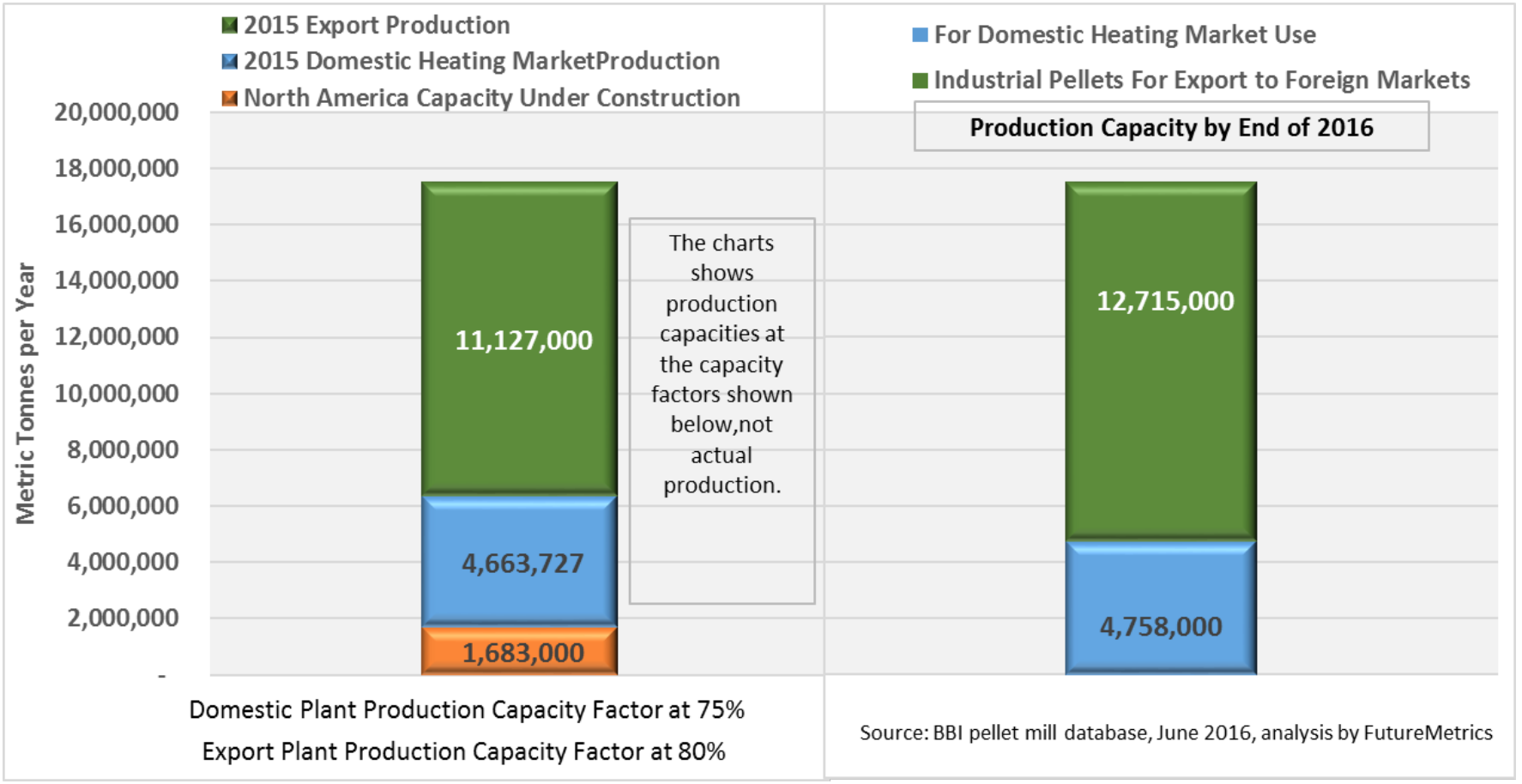
Industrial Pellet Markets



US is contingent on the Clean Power Plan. Canada is assuming Alberta and other provinces co-firing and full-firing.


Industrial Pellet Demand in 2015 - in metric tonnes
Rest of World, 272,000, 2%
South Korea, 2,040,000, 15%
Japan, 136,000, 1%
Other EU, 952,000, 7%
Belgium, 1,224,000, 9%
Denmark, 1,496,000, 11%
Sweden, 1,632,000, 12%
UK, 5,848,000, 43%
Total Demand = about 13,600,000 tonnes
Data from Hawkins Wright, Dec., 2015

North American Current Capacity



Pellet Production

Sawdust or Chips ➔ Dry ➔ Mill ➔ Densify in Pellet Presses ➔ Cool and Condition ➔ Store ➔ Transport

Photo of Fram Renewable Fuels 475,000 ton per year plant in Hazelhurst GA, built by Astec Industries

Baseload generation with almost zero carbon emissions is only possible with two low carbon fuels.

Nuclear generation provides zero carbon in “combustion”.

The only other fuel that provides zero carbon in combustion and dispatchable generation is industrial wood pellets.

Drax Biomass 450,000 ton per year pellet fuel production plant.

How are Pellets Considered Carbon Neutral in Combustion?

No fuel that has to be mined, harvested, extracted, refined, and transported is carbon neutral. Fuel passing along supply chains that use fossil fuel gathers a carbon footprint as the fuel makes its way to the power station.

Adding to that footprint is the CO_2 released in combustion by fossil fuels, including natural gas, which permanently increases the stock of CO_2 in the atmosphere.

But wood pellets are a refined solid power-plant fuel that is derived from a renewing feedstock that captures carbon.

Industrial wood pellets used in power plants to achieve carbon emissions reductions must be derived from certified sustainable feedstocks.

Carbon Neutral in Combustion?

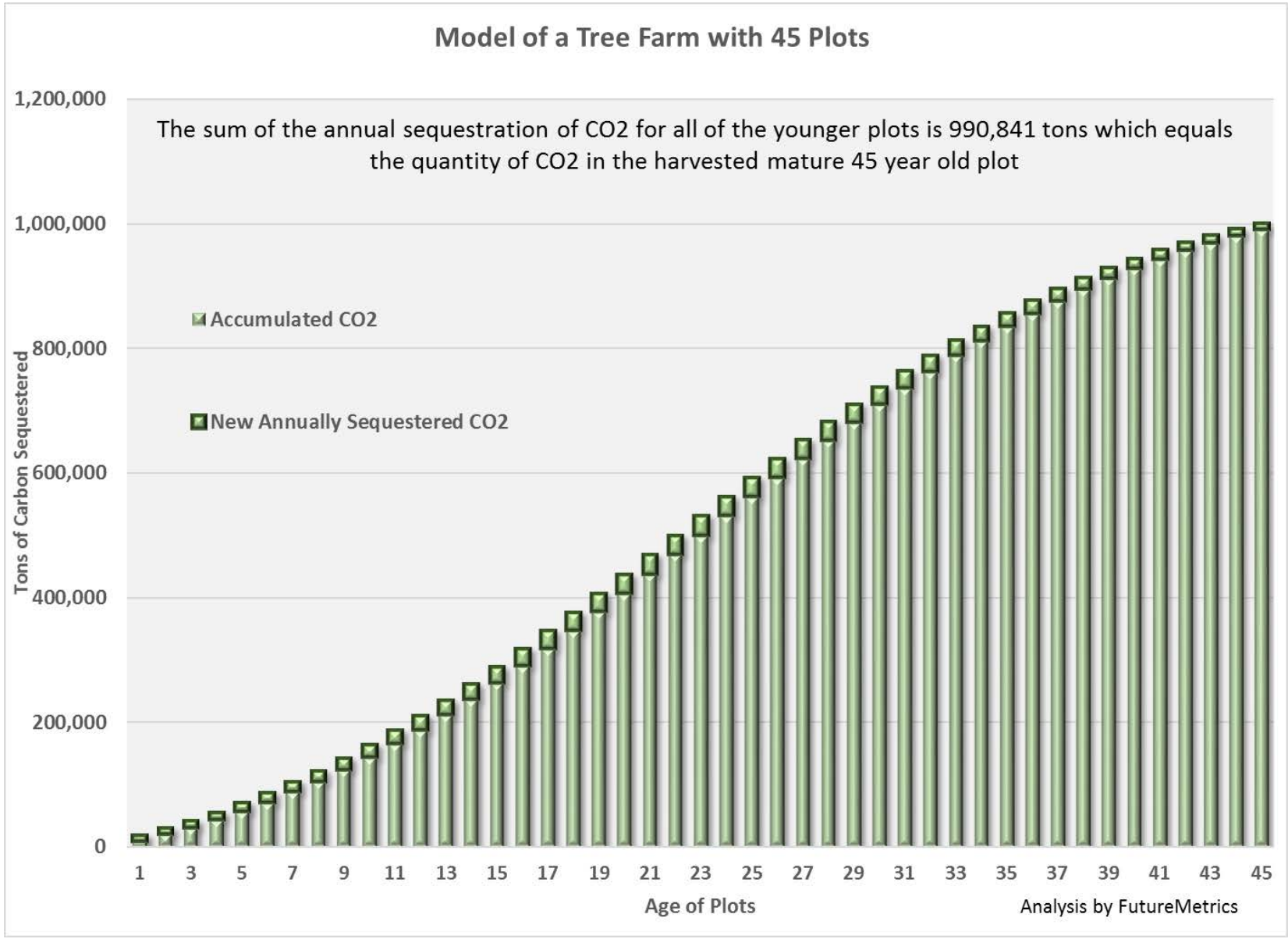
The fundamental criteria for carbon neutrality in combustion is that the stock of carbon in the atmosphere cannot be increased by the use of the fuel.

Here is how that works for industrial wood pellets:

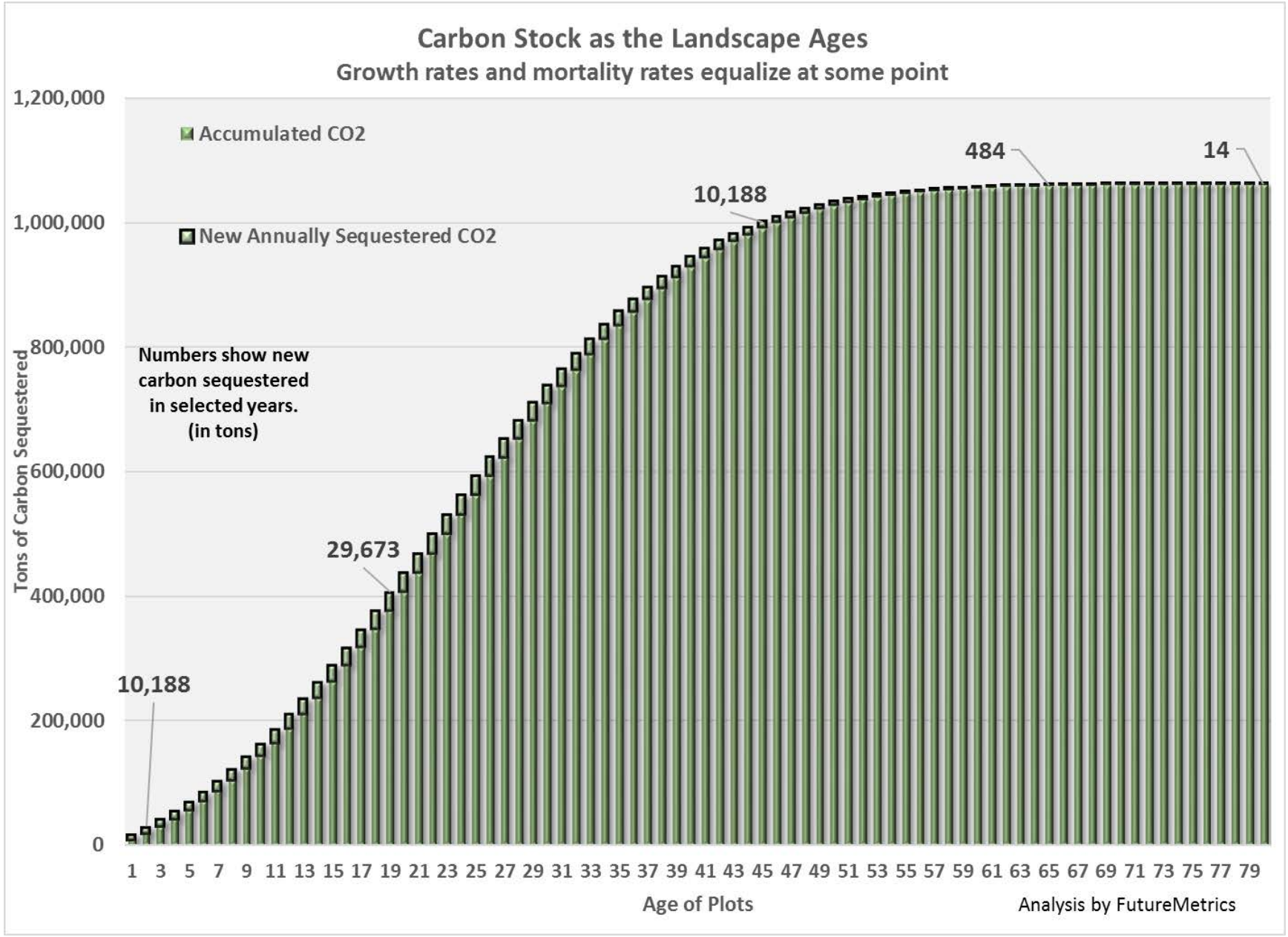
- The source of material for producing the pellets has to be a forest that is certified to be managed sustainably.
- Sustainable management means that the forest cannot be allowed to shrink in size.
- A forest that does not shrink in size also means that the stock of carbon held in the forest does not shrink.
- For example, the raw materials for the pellet production plant are procured from a forest tenure that produce new growth at a rate of 1,000,000 tons per year.
- The daily harvest is about 1 million divided by 365 or about 2,740 tons per day.
- Those tons are converted to roughly 1,400 tons per day of industrial pellets (about 500,000 tons per year)*.
- Those pellets are co-fired in a pulverized coal power plant as low carbon fuel. The supply chain carbon still counts for pellets just as it does for coal; but the net is that pellets produce about 88% less carbon emissions than coal for the same MWh's.
- The carbon released by the combustion of 1,400 tons of pellets is absorbed contemporaneously by the 2,740 tons of new growth that same day.
- There is no net new carbon added to the atmosphere.

*A 600 MW PC boiler would consume about 165,000 tonnes per year of pellets co-firing at a 10% rate.
At 100% pellets the consumption would be about 2.2 million tonnes per year.
A typical industrial pellet mill in western Canada will produce 300,000 – 500,000 tons per year.

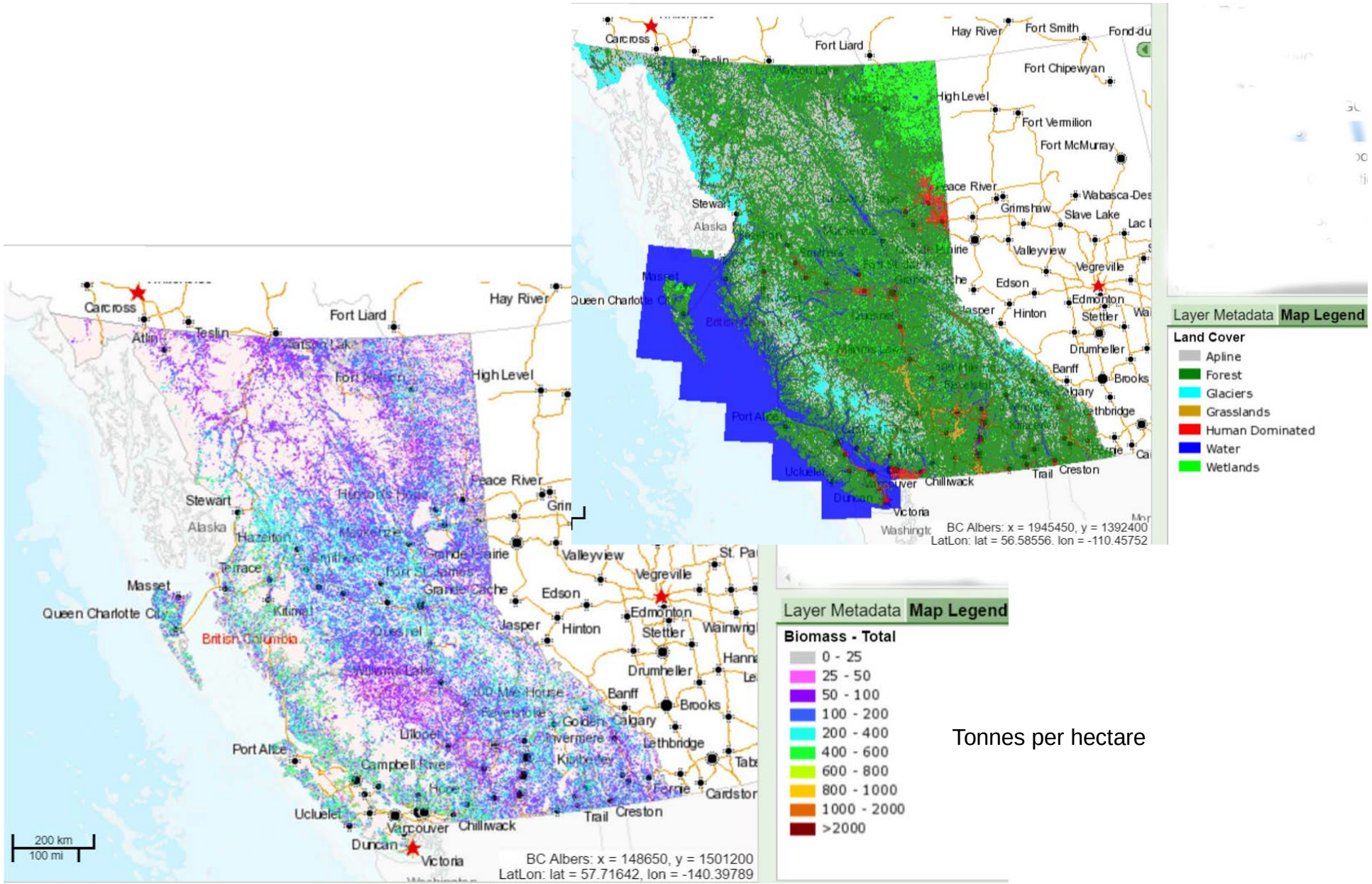
This tree farm model shows that the total annual new carbon sequestered equals the amount of carbon contained in the oldest plot. So carbon released from combustion of plot 45 is sequestered the same year by all the other growing plots. The chart shows tons of carbon sequesters.



Carbon sequestration trends to zero as plots age. So there is very little added sequestration benefit to allowing the plots to continue growing.

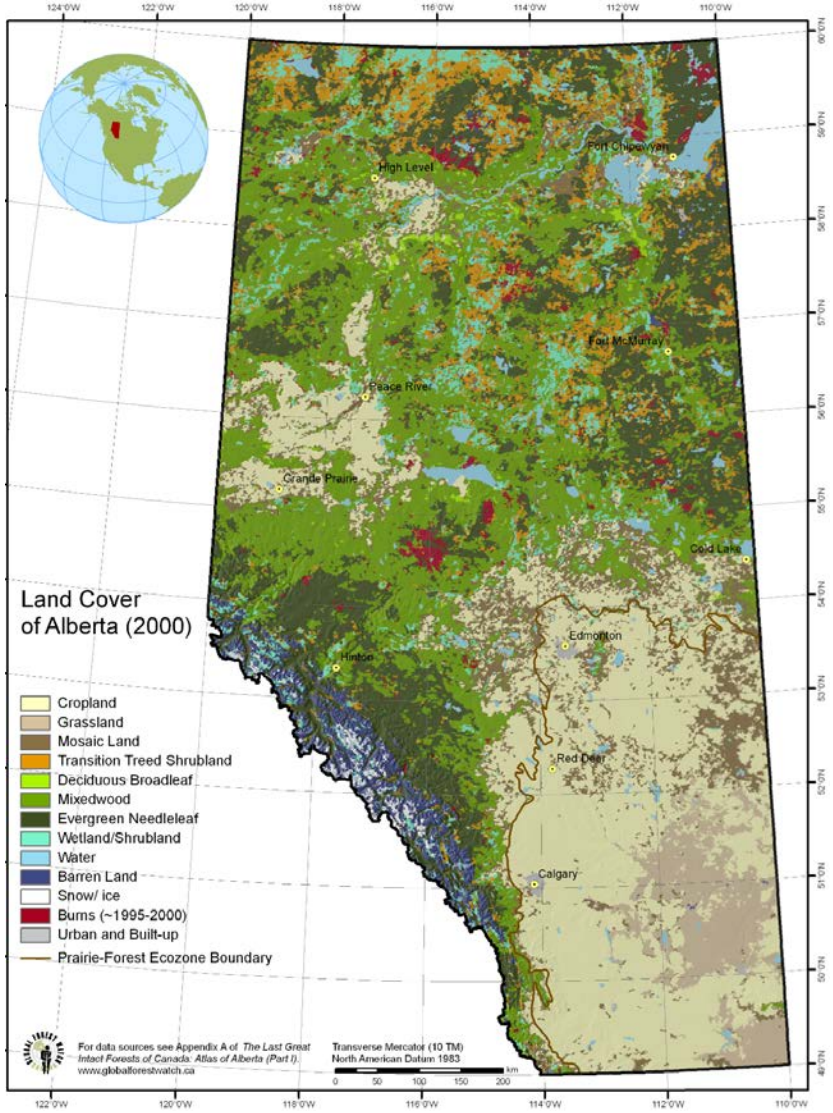


Is there enough pellet feedstock in BC and Alberta to supply pellets to PC power plants?



Tonnes per hectare

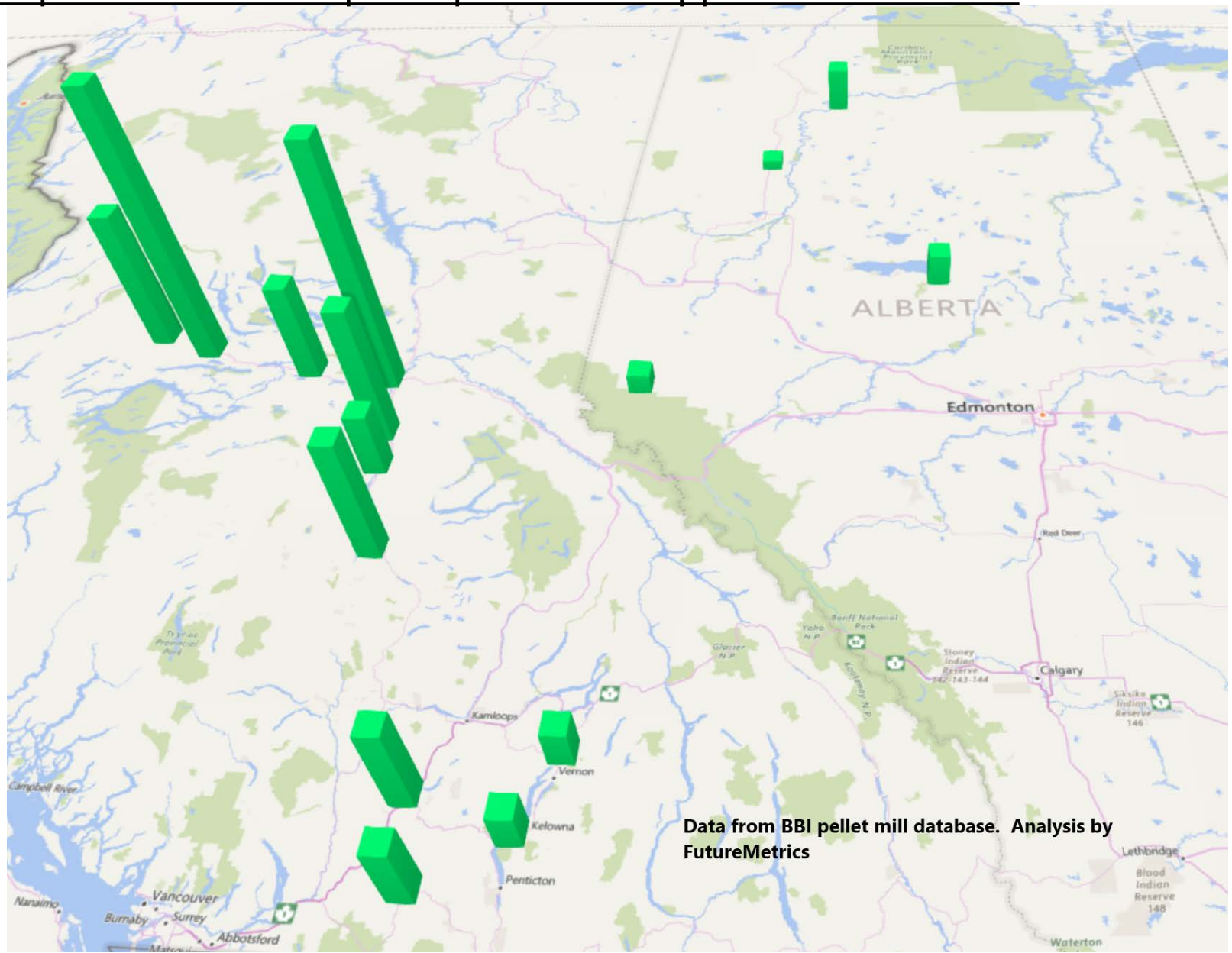
Alberta has a robust forest products industry



Pellet mills in western Canada
are export oriented. So they are on rail with good mill-to-port logistics.
Unexploited industrial pellet production opportunities inland!

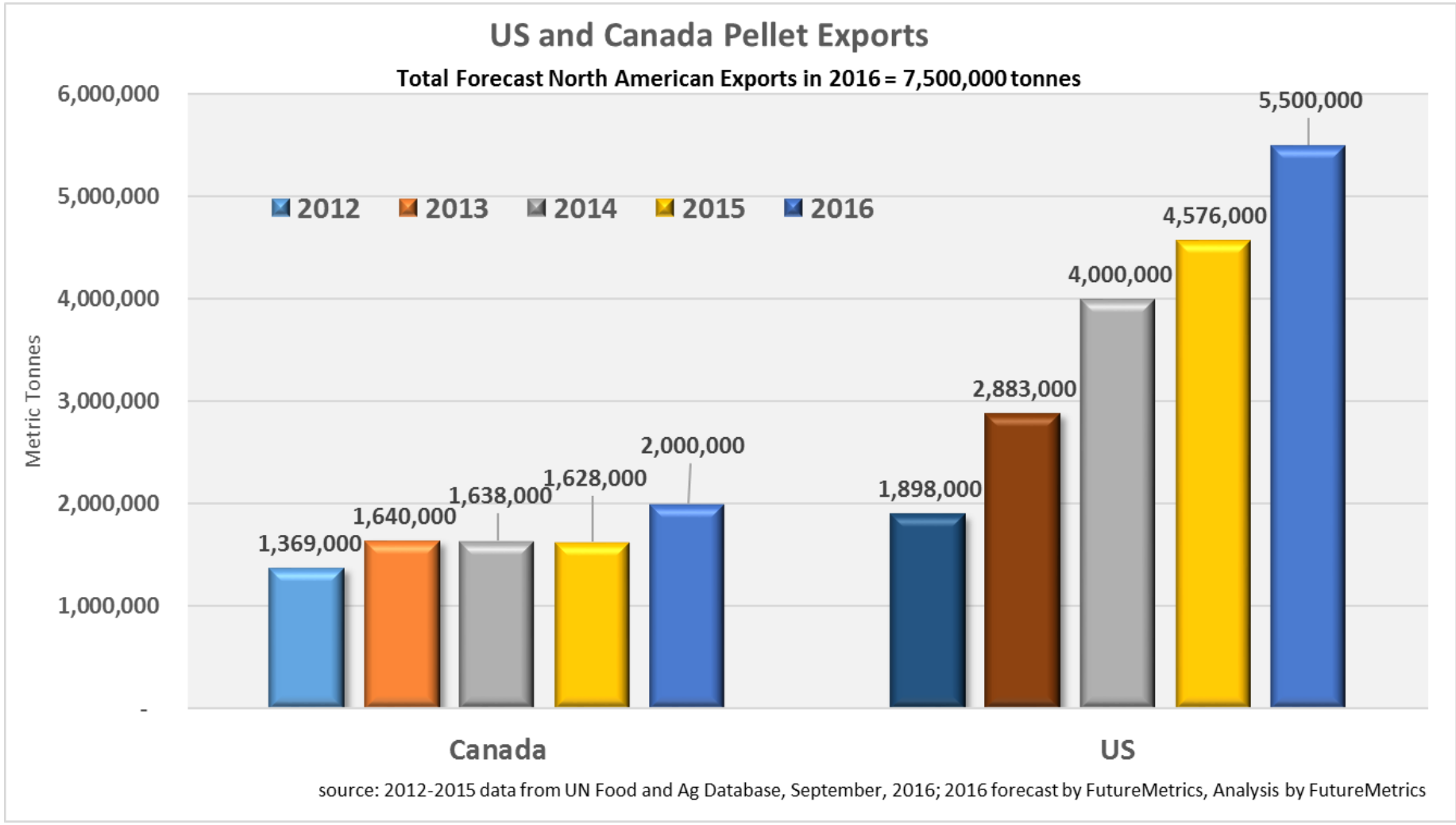
Location of pellet mills.

Bar height relates to their annual output capacity.



Industrial Wood Pellets are Used Now in Large Power Stations
Throughout the World for Carbon Mitigation

Using pellets in pulverized coal plants is NOT anything like using green unrefined wood chips in stokers or fluid bed boilers!



For Alberta, which remains highly dependent on coal for power generation, a solution that leverages its existing coal assets makes a lot of sense.

Alberta's Electricity Generation - 2015

As of December 2015

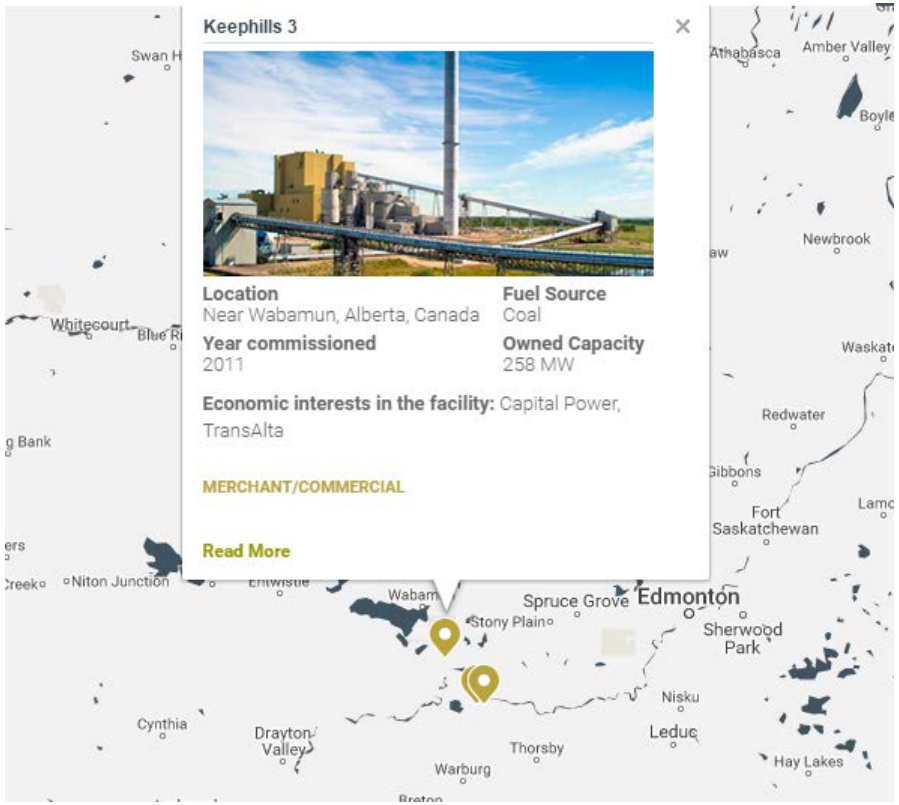
Generation	Gigawatt Hour (GWh)	Generation Share By Fuel
Coal	41,378	51%
Natural Gas	32,215	39%
Hydro	1,745	2%
Wind	3,816	5%
Biomass	2,149	3%
Others*	318	0%
Total	**81,621**	**100%**

*Others include fuel oil and waste heat

Source: Alberta Utilities Commission (AUC)

At least one plant, the 5 year old Keephills Unit 3, may be a candidate for a full conversion. Genesse #3 also…

Alberta's Coal-fired Power Fleet			
	Capacity (MW)	Year Completed	Age
Battle River			
3	150	1969	47
4	150	1975	41
5	370	1981	35
Genesee			
1	410	1989	27
2	410	1994	22
3	495	2005	11
HR Milner 1	150	1972	44
Keephills			
1	406	1983	33
2	409	1983	33
3	495	2011	5
Sheerness			
1	380	1986	30
2	380	1990	26
Sundance			
1	280	1970	46
2	80	1973	43
3	406	1976	40
4	392	1977	39
5	392	1978	38
6	392	1980	36
Averages ==>	**341.5**		**33**



Keephills #3 is a 50/50 joint ownership between Capital Power and TransAlta.

It cost $1.98 billion to build. It is less than 5 years old.

It is a 495 MW high-efficiency super-critical PC power plant about 70 km west of Edmonton.

A similar scenario could be told about the Genesee #3 plant which is not far from the Keephills #3 station.

It is also a JV with Capital Power and TransAlta and is about the same size as Keephills #3 and is just 11 years old.

Each plant if fully converted would consume about 1.7 million tonnes per year of pellets.

Alberta's Coal-fired Power Fleet				
	Capacity (MW)	Year Completed	Age	Age in 2030
Battle River				
3	150	1969	47	61
4	150	1975	41	55
5	370	1981	35	49
Genesee				
1	410	1989	27	41
2	410	1994	22	36
3	495	2005	11	25
HR Milner 1	150	1972	44	58
Keephills				
1	406	1983	33	47
2	409	1983	33	47
3	495	2011	5	19
Sheerness				
1	380	1986	30	44
2	380	1990	26	40
Sundance				
1	280	1970	46	60
2	80	1973	43	57
3	406	1976	40	54
4	392	1977	39	53
5	392	1978	38	52
6	392	1980	36	50
Averages ==>	**341.5**		**33**	**47**

By 2030 most of Alberta's coal fleet will be over 50 years old.

The province will have grid reliability challenges if all those plants retire and other dispatchable baseload or peaking generation is not in place by 2030.

New Natural Gas Plants are Probable…

Except for the new coal stations.

One would expect that the utility would prefer to not strand these very new, highly efficient, and costly assets.

What are the Costs of Co-firing

Plant Modifications (more on this in the next presentation)

In all cases, the pellet fuel has to be kept dry. The size of the dry storage solution depends on the expected daily consumption of wood pellets. Two weeks of fuel storage is a nominal baseline for sizing the storage.

At low co-firing rates, modifications to the fuel feed and burner systems are minimal or not needed.

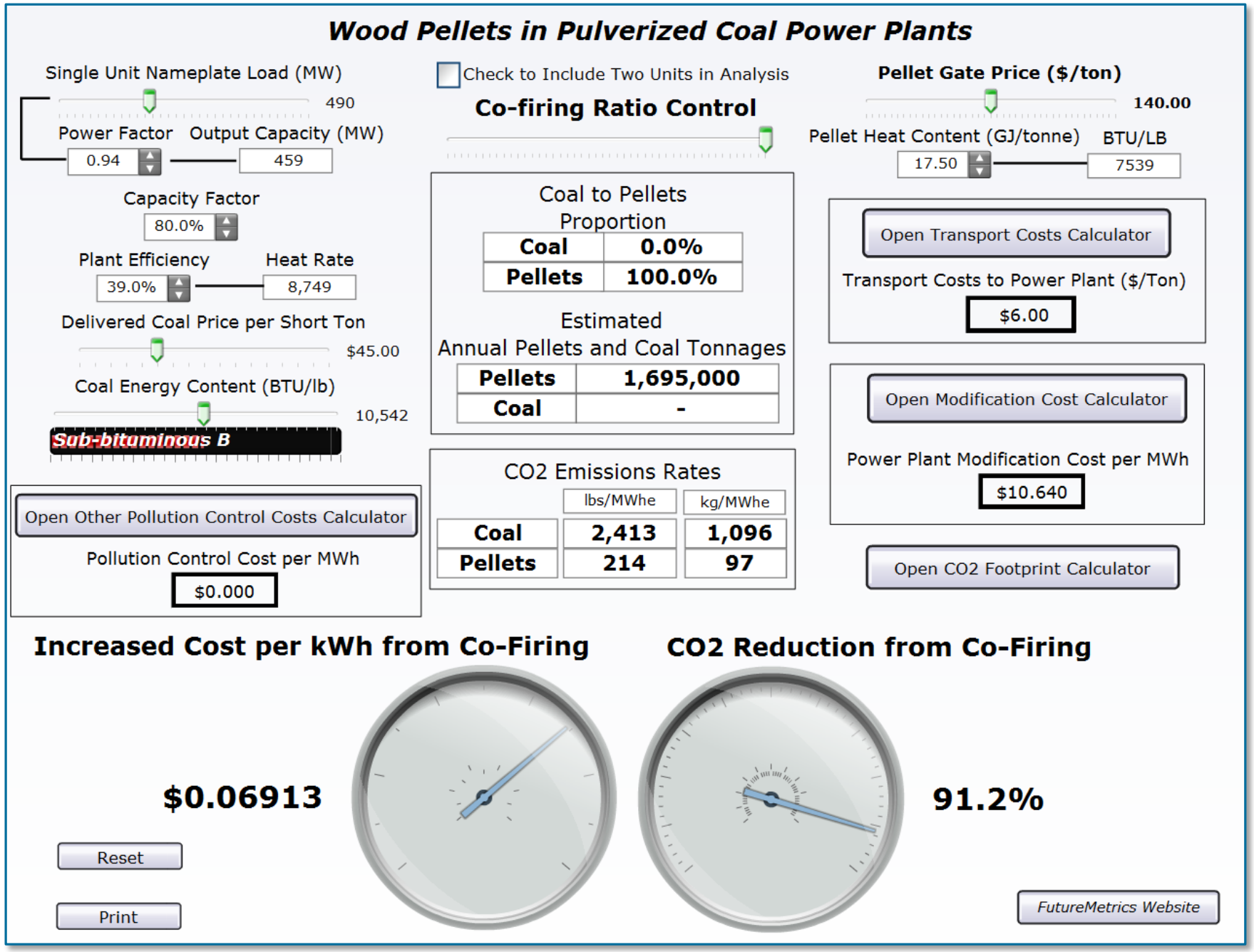
At power stations that are 100% firing pellets, the cost of conversion per installed kW is between $450 and $700. About half of that is for the dry storage domes or silos and the associated safety equipment. The other half is for pulverizer, burner, and other modifications or retrofits.

Depending on the expected highest co-firing rate, the equipment cost will be between nil and $450 - $700 per kW of capacity.

Keephills #3 would consume about 1.7 million metric tonnes per year under a full conversion.

Increased cost over current cost of generation with coal, based on assumptions shown, would be about 6.9 cents per kWh.

That increase in cost of generation ($69/MWh) has to have policy support to allow the utility to remain profitable.



How Do Co-firing Costs Compare to Other Low Carbon Generation Technologies?

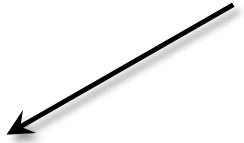
First, wind and solar are intermittent. **Every MW of wind and solar needs a conventional (thermal) generation backup.**

To provide reliable baseload or on-demand peaking power, hydro or thermal generation is needed.

How Do Full-Firing Costs Compare to Other Low Carbon Generation Technologies?

CO2 Reduction	**91.3%**
Co-firing to Reach about 91% CO2 Reduction	
Coal Consumption Percentage	0.0%
Wood Pellet Consumption Percentage	100.0%
Coal Consumption Cost	$ -
Pellet Consumption Cost	$ 295,000,000
Annualized Conversion Cost	$27,900,000
Other Pollution Control Annual Cost	$ -
Total Full-firing Cost	**$ 322,900,000**
Net Cost per MWh	**$ 93.08**

Cost with wood pellet fuel



Pellet fuel provides the lowest cost dispatchable low carbon generation pathway other than hydro.

US Average Levelized Costs with Assumed Capacity Factors (2015 $/MWh) for Plants Entering Service in 2040

Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System LCOE
Low Carbon Technologies						
Wind	40%	$ 42.80	$ 13.20	$ -	$ 2.80	$ 58.80
Wind – Offshore	45%	$ 109.60	$ 19.30	$ -	$ 4.80	$133.70
Solar PV	25%	$ 57.30	$ 9.90	$ -	$ 4.10	$ 71.20
Solar Thermal	20%	$ 155.70	$ 43.30	$ -	$ 6.00	$205.00
Hydroelectric	57%	$ 54.10	$ 3.60	$ 5.80	$ 1.90	$ 65.30

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2016*, August 2016.

We question the 40% and 45% capacity factors for wind and the transmission investments!

How is the Utility Compensated for the Higher Cost of Generation?

The generator could simply pass through the cost. No policy support!

The generator could simply pass through the cost.

The rate increase for the end user can be roughly estimated by a weighted average of the rates at co-firing or full-firing plants and the cost for all the other power delivered in the province.

Suppose the province produces about 80,000,000 MWh's in a given year*. The 495 MW Keephills 3 plant will generate about 3,300,000 MWh's or about 4.1% of the total in the province.

A simple calculation suggests that 4.1% of the $69.13/MWh incremental increase at the 100% full-firing rate is about $2.85/MWh.

That would be the diluted theoretical incremental increase in rates.

That is about three tenths of a penny per kWh: $0.00285 !

*Alberta Utilities Commission data shows Alberta consumed 81,621,000 MWh's in 2015

Contract for difference (CfD) – Policy Support

The government could implement a scheme similar to that used in Great Britain. The contract for difference sets a price per MWh that is high enough to allow the utility to maintain a reasonable business model and thus fulfill its obligations for reliability. The CfD pays the difference between the market price and the CfD strike price. Assume carbon is trading for $50/ton.

The difference that the CfD would pay after income from carbon trading in 2030 is about $143 million.

CO2 Reduction	**91.3%**
Co-firing to Reach about 91% CO2 Reduction	
Coal Consumption Percentage	0.0%
Wood Pellet Consumption Percentage	100.0%
Coal Consumption Cost	$ -
Pellet Consumption Cost	$ 295,000,000
Annualized Conversion Cost	$27,900,000
Other Pollution Control Annual Cost	$ -
Total Full-firing Cost	**$ 322,900,000**
Net Cost per MWh	**$ 93.08**
CO2 Income	$ 179,453,810
Net added Cost after CO2 Trades at $50 /ton	$ 143,446,190
Total Cost per MWh after Carbon Tax Income	$ 41.35
Annual Differential between cofiring and coal	$ (233,699,000)
Coal Only versus Co-firing Differential ($/MWh)	**$67.369**

Assuming a provincial budget of $55,000,000,000 in 2030*.

The 2030 cost is a bit more than one fourth of one percent of the annual budget – 0.0268%

*Alberta budget for 2018-19 is $49.6 billion

Summary

Blending industrial wood pellets with coal is a proven easy to implement and low cost solution to carbon emission reduction that delivers baseload or on-demand power.

This pathway to compliance should be recognized as a valuable component in the portfolio of carbon reduction strategies and should be explicitly supported by utilities and policymakers.

Conclusion

There is a real potential for demand for pellets in Alberta's power sector.

But both the utilities and the policymakers need to know the benefits.

When placed in the context of the entire generating fleet and/or the provincial budget, the cost is almost a rounding error.

Given the current national policy directions on carbon emissions, Alberta could lead the way with action way sooner than 2030.

Policymakers need to hear the story, understand the economics, and know that the power stations can use pellets with no loss of reliability or output.

Thank you – William Strauss
WilliamStrauss@FutureMetrics.com

Bill Strauss Near Revelstoke, BC in Feb., 2016