What Is the Future of the Industrial Wood Pellet Market? What Countries Will Drive Markets in the 2020s. Will 'Black' Pellets Be Part of That Growth?

Presented by William Strauss, PhD
President, FutureMetrics
April 11, 2018

FutureMetrics

Intelligent Analysis, Operations Guidance, and Strategic Leadership for the Pellet Sector

8 Airport Road
Bethel, ME 04217, USA
www.FutureMetrics.com

Senior Members of the FutureMetrics Team

Dr. William Strauss, President

Named one of the most influential leaders in the biomass sector in 2016 and 2017 by Argus Media. Recipient of the 2012 International Excellence in Bioenergy Award.
A leader in the industry for two decades.

John Swaan, Pellet Plant Operations

Recipient of the 2014 International Founders Award.
Founder of Pacific BioEnergy and producer of the first shipment of wood pellets from North America to Europe (1998).
Leading expert on pellet plant operations.

Seth Walker, Senior Economist

A leading and often cited researcher, analyst, and author in the wood pellet sector.
Has presented at dozens of conferences throughout the world.

Laurenz Schmidt, Technology Specialist

Globally respected expert in thermodynamics and mass and energy flow dynamics.
Has authored FutureMetrics analyses of steam exploded pellet production.

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

Selection of Current and Recent Clients

Overview of Global Pellet Markets

Why Japan and South Korea are Important

(and why the industrial wood pellet industry exists!)

This is the twenty-year Anniversary of the Beginning of the North American Industrial Wood Pellet Export Era

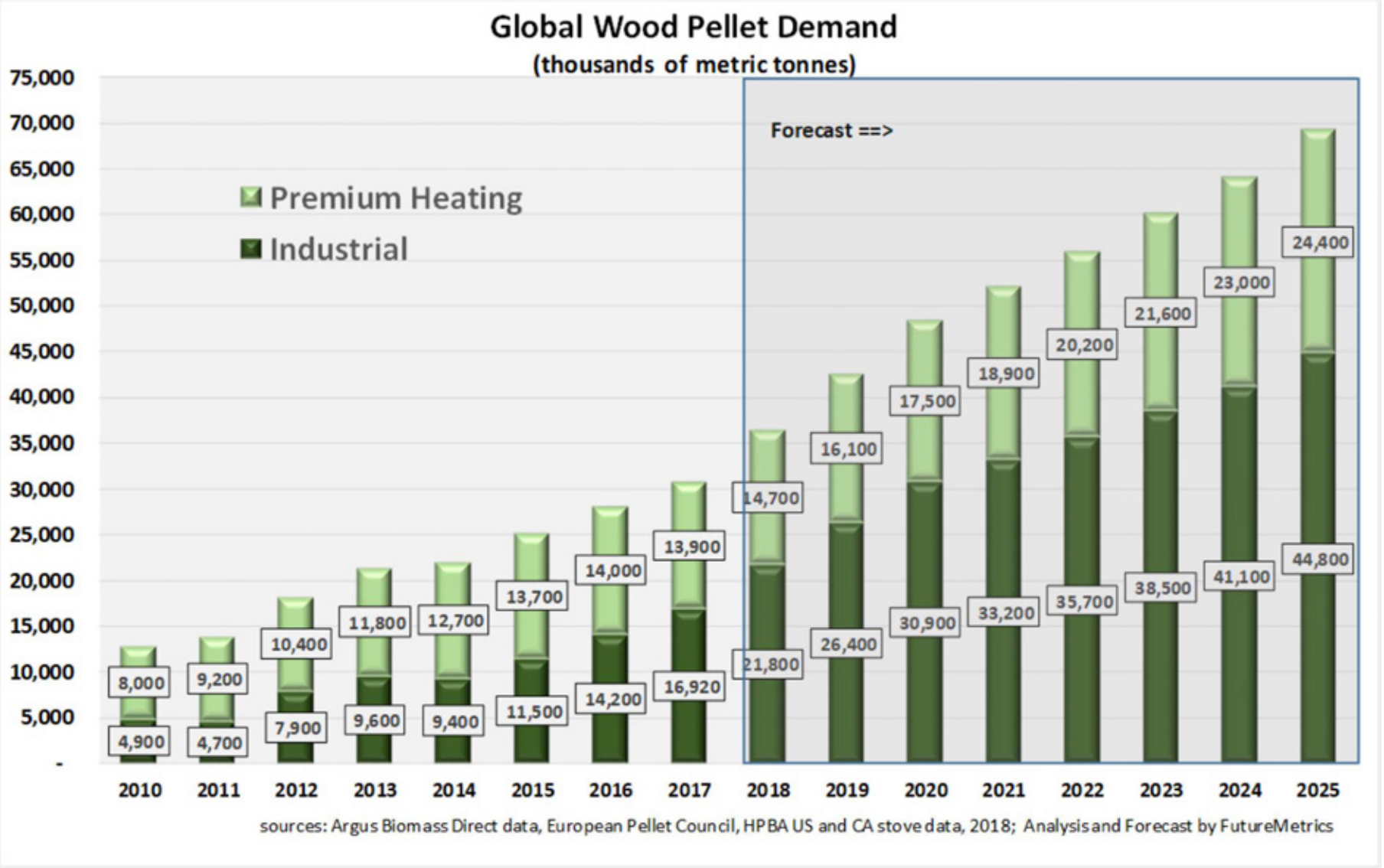
20 years ago on April 6th 1998, the first trans-ocean bulk shipment of wood pellets from north America, which were carried on the "Mandarin Moon", arrived and began discharging 15,000 metric tonnes of wood pellets at the port of Helsingborg, Sweden.

FutureMetrics' partner and operations expert, John Swaan, entered into the first offtake agreement for bulk pellet delivery from north America, produced the pellets at his pellet plant in Prince George, BC, and loaded the ship in Prince Rupert, BC on February 9, 1998.

Thee two major markets for pellets:

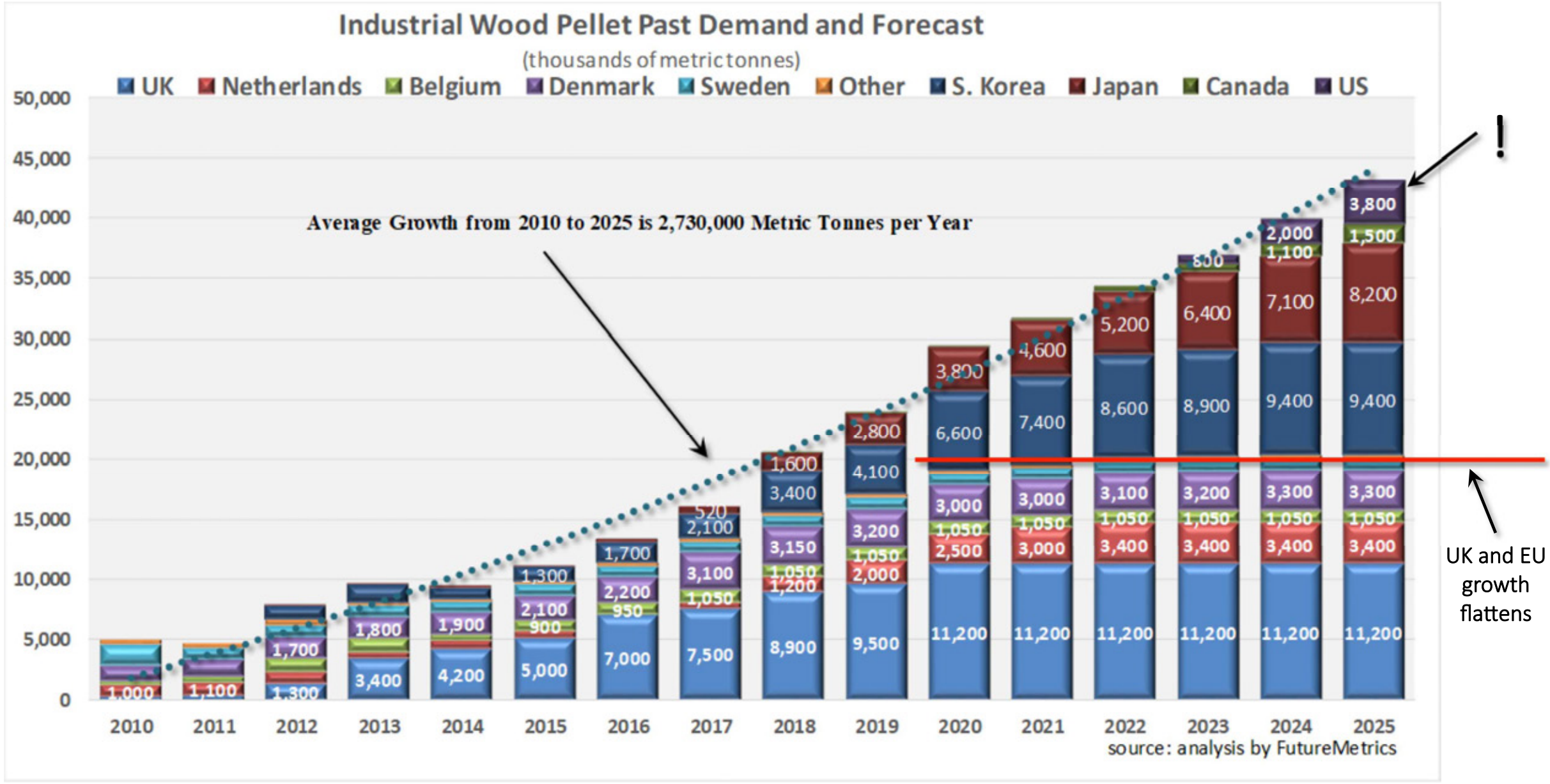
(1) **Industrial pellets** used as a substitute for coal in large utility power stations;

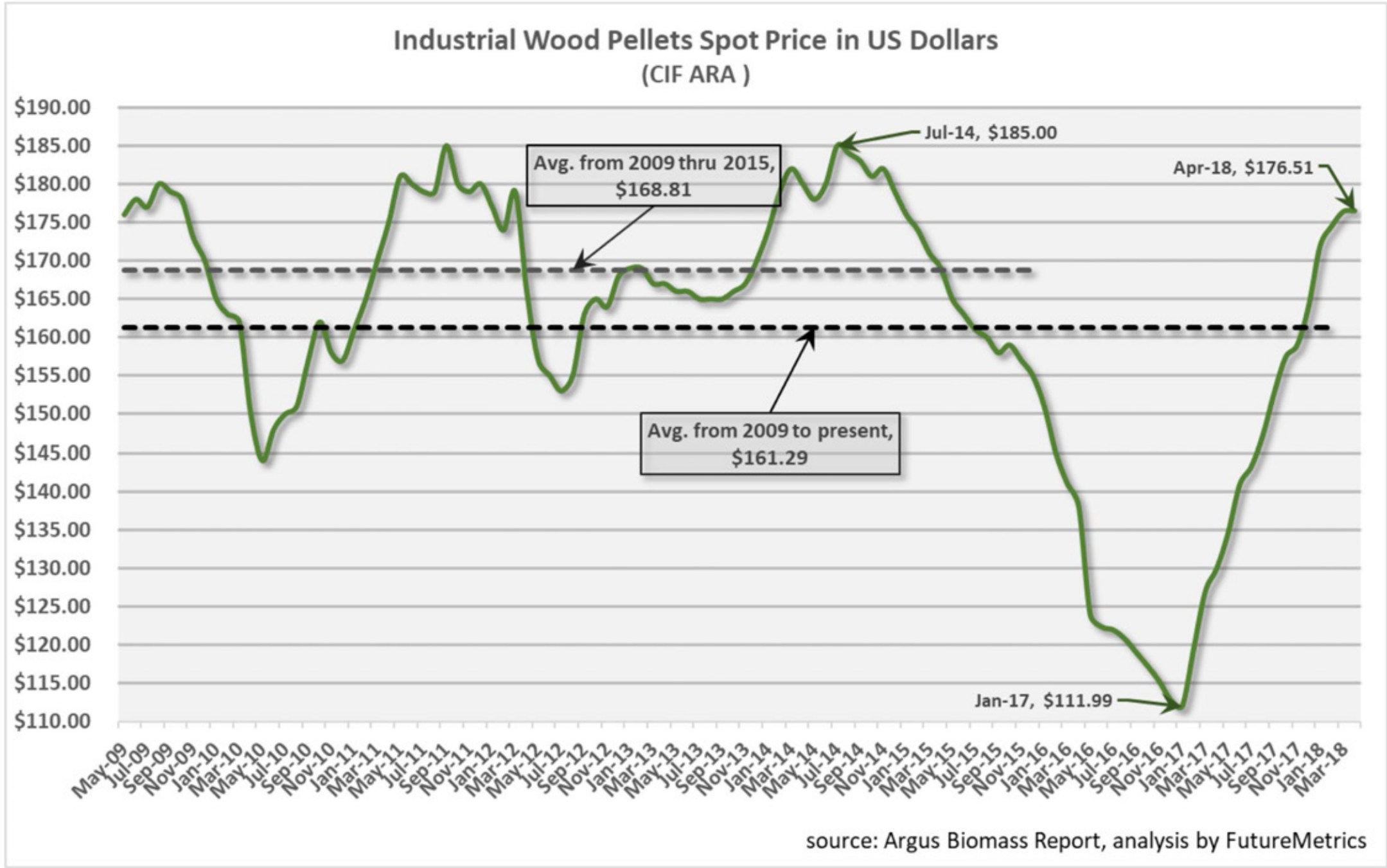
(2) **Premium heating** pellets used in pellet stoves and pellet fueled central heating systems.



Industrial Pellet Markets

EU and UK growth flat after 2020.
Japan and S. Korea dominate the expected growth in the 2020's




Industrial Wood Pellets Spot Price in US Dollars
(CIF ARA)
$190.00
$185.00
$180.00
$175.00
$170.00
$165.00
$160.00
$155.00
$150.00
$145.00
$140.00
$135.00
$130.00
$125.00
$120.00
$115.00
$110.00
Avg. from 2009 thru 2015, $168.81
Avg. from 2009 to present, $161.29
Jul-14, $185.00
Apr-18, $176.51
Jan-17, $111.99
May-09
Jul-09
Sep-09
Nov-09
Jan-10
Mar-10
May-10
Jul-10
Sep-10
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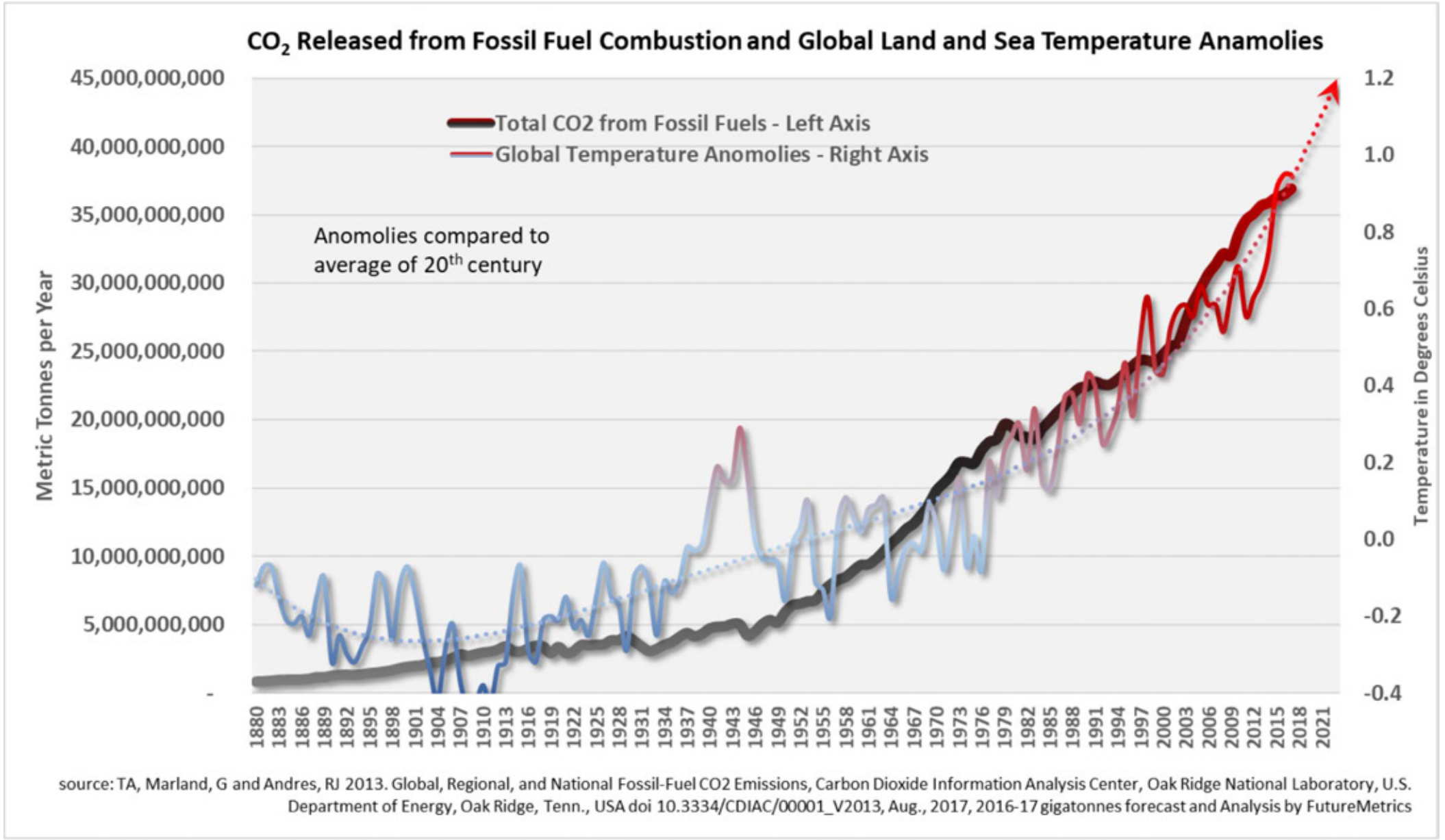
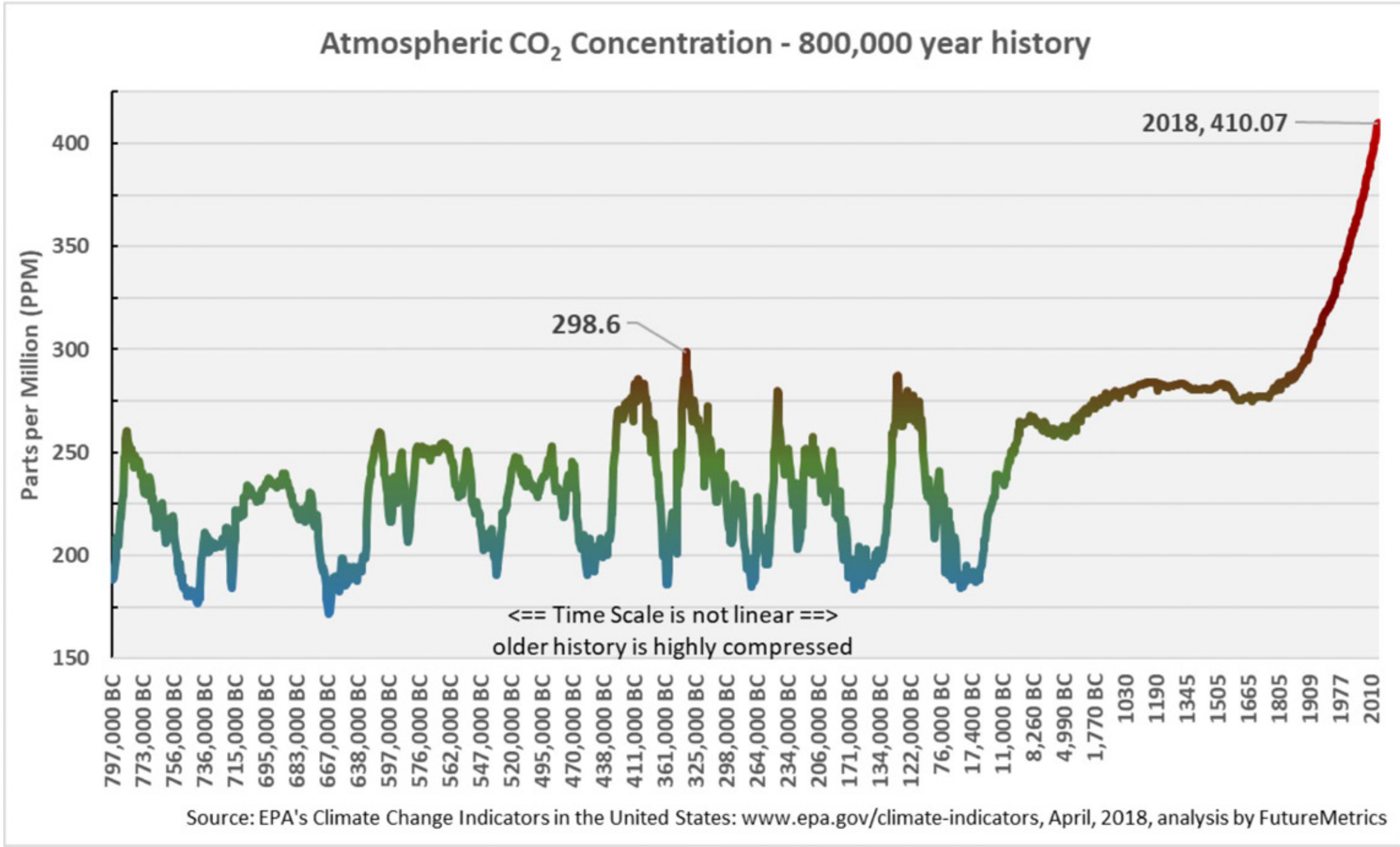
Mar-18
source: Argus Biomass Report, analysis by FutureMetrics

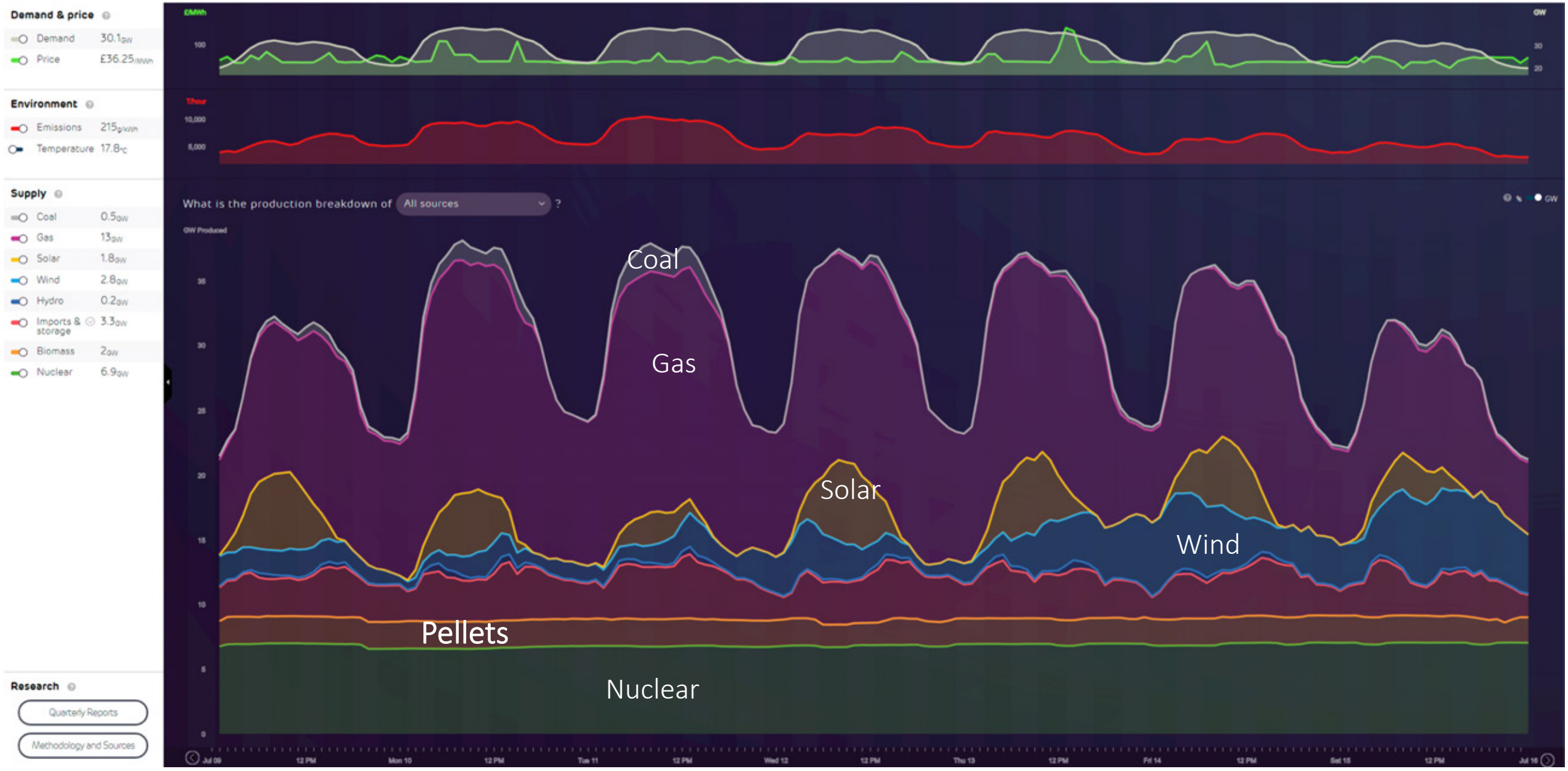
Three Charts Showing Why We Need Pellets for Power




Atmospheric CO_2 Concentration - 800,000 year history
Parts per Million (PPM)
400
350
300
250
200
150
2018, 410.07
298.6
<== Time Scale is not linear ==>
older history is highly compressed
797,000 BC
773,000 BC
756,000 BC
736,000 BC
715,000 BC
695,000 BC
683,000 BC
667,000 BC
638,000 BC
597,000 BC
576,000 BC
562,000 BC
547,000 BC
520,000 BC
495,000 BC
470,000 BC
438,000 BC
411,000 BC
361,000 BC
325,000 BC
298,000 BC
264,000 BC
234,000 BC
206,000 BC
171,000 BC
134,000 BC
122,000 BC
76,000 BC
17,400 BC
11,000 BC
8,260 BC
4,990 BC
1,770 BC
1030
1190
1345
1505
1665
1805
1909
1977
2010
Source: EPA's Climate Change Indicators in the United States: www.epa.gov/climate-indicators, April, 2018, analysis by FutureMetrics

Over one week in the UK we can see how wind and solar fluctuate dramatically.

<u>The grid needs steady reliable low-cost baseload low-carbon power</u>.



The foundation of carbon emissions mitigation from the use of wood pellets is because the NET carbon added to the atmosphere from the combustion of wood pellets is **ZERO.**

The foundation for zero carbon emissions is the SUSTAINABLITY OF THE FOREST RESOURCES.

As long as the growth rate equals or exceeds the harvest rate, the net stock of carbon held in the forest landscape is held constant or is increasing and the **atmosphere sees no net new carbon dioxide**.

Sustainably produced pellets as a substitute for coal in power plants is a well-established option that should be included in all strategies for

a rational and reliable transition to a more decarbonized future.

Europe and the UK

They have driven the growth of the industrial pellet markets

How much new demand will they create?

Major New Industrial Wood Pellet Projects in Europe

Country	Company	Project	Ratio	Estimated Pellet Demand by 2022
Netherlands	RWE Essent	Amer 9	Co-firing at 50%	1,163,000
Netherlands	Engie, formerly GDF Suez	Rotterdam 1	Co-firing at 10%	283,000
Netherlands	Uniper	Maasvlakte 3 (MPP3)	Co-firing at 15%	628,000
Netherlands	RWE Essent	Eemshaven A and B	Co-firing at 15%	452,000
Netherlands Total				**2,526,000**
UK	EPH	Lynemouth	Full-firing at 100%	1,535,000
UK	MGT Power	Teesside	Full-firing at 100%	1,159,000
UK	Drax	Selby (Unit 4)	Full-firing at 25%	625,000
UK	Simec Uskmouth Power	Uskmouth	Full-firing at 100%	1,407,000
UK Total				**4,726,000**
EU/UK Total minus Simec				**5,845,000**

In 2016, with a higher budget available in the Netherlands, RWE, Engie and Uniper were successful in securing subsidies that will allow them to co-fire up to ~3.5 million MT annually.

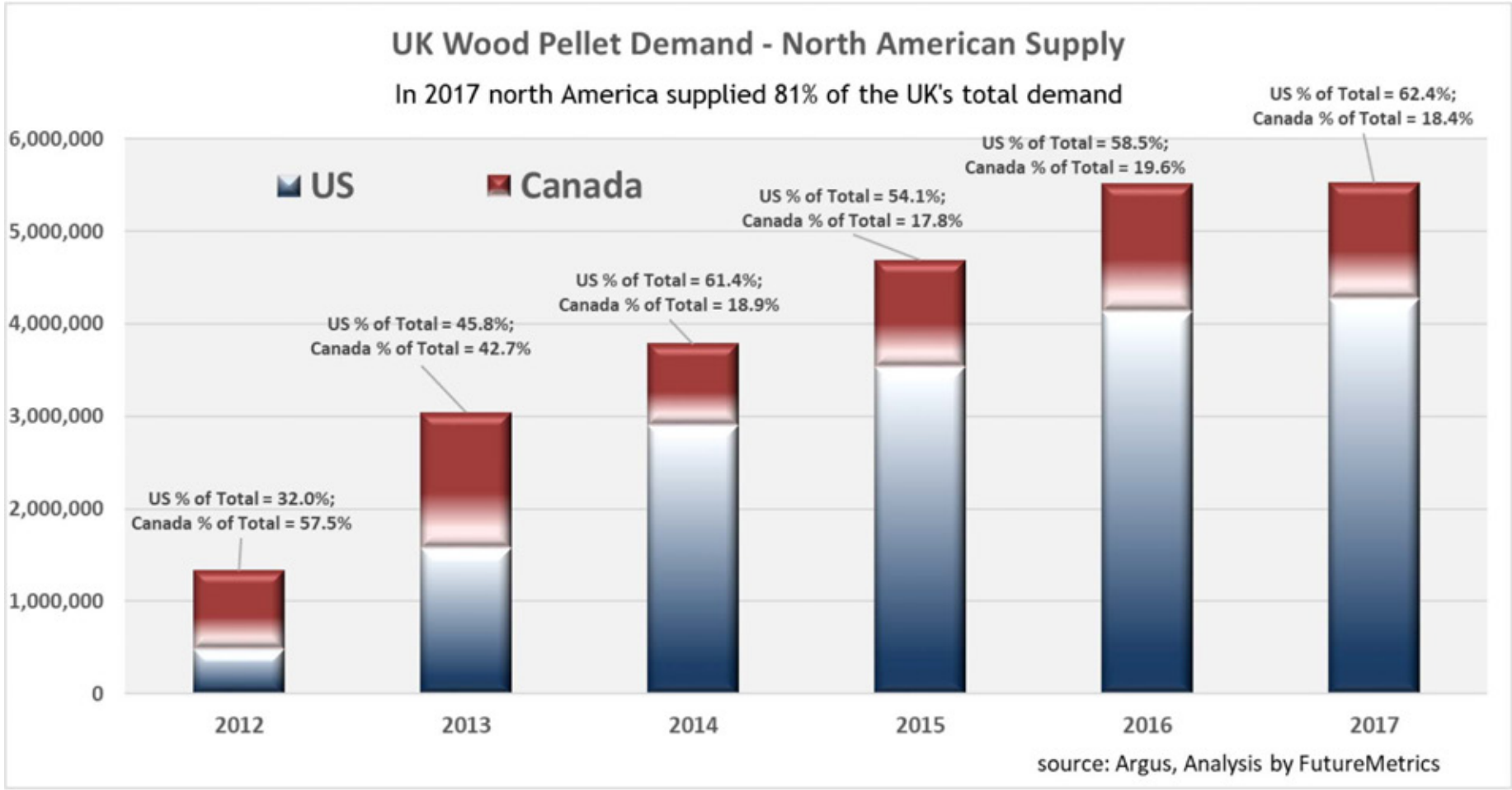
Two UK projects, EPH Lynemouth and MGT Teeside are currently either under construction or already undergoing commissioning. The Lynemouth project is expected to be at full capacity by summer 2018. Drax has recently announced the conversion of unit 4 from coal to pellets. The expectation is that this will allow the Drax station to generate more consistently around unplanned and planned unit outages. Based on information obtained by FutureMetrics, we expect that the incremental increase in annual aggregate demand by the Drax power station will be about 625,000 tonnes per year. That is represented in the table above by plugging in a 25% capacity factor into the full-firing estimated demand.

Denmark's wood pellet imports jumped 50% in 2017 to a record 3.1 million MT. Much of the growth was a result of further conversions of central power stations by Danish utility Ørsted (formerly Dong Energy). Ørsted has reduced its coal consumption from 6.2 million MT in 2006 to 1.1 million MT in 2017 and plans to eliminate all coal consumption by 2023. Most additional conversions plan to use woodchips or other low-grade material so further growth in wood pellet demand will likely be on a more moderate pace.

The total new likely demand in Europe and England is about 5.85 million tonnes per year.

Demand will settle to at about 19 – 20 million tonnes per year by 2022

The US and Canada have been the major suppliers to the UK and will continue to be the dominant suppliers for industrial pellets to the UK



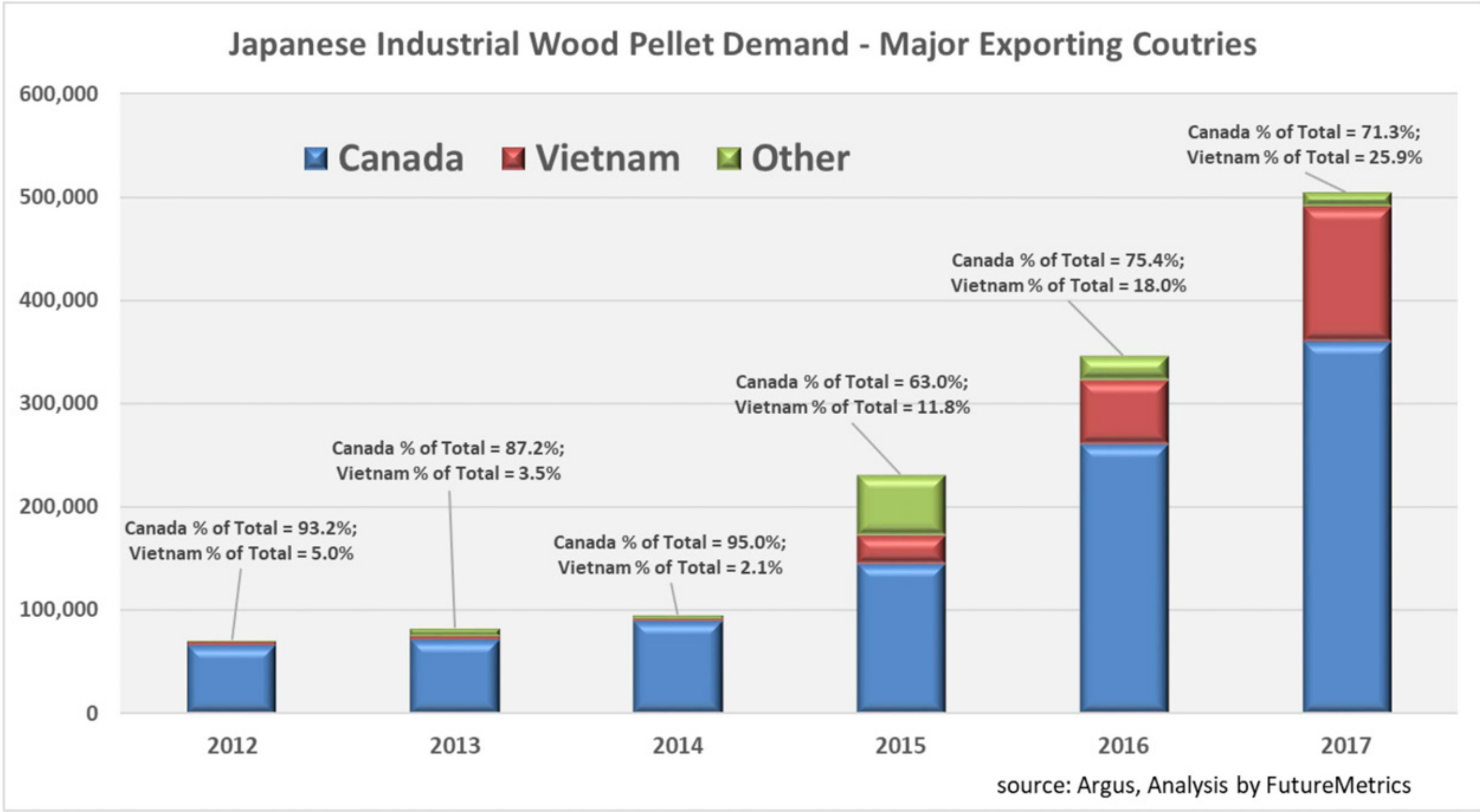
The Baltic states are the major suppliers of industrial pellets to Denmark.

The US is the largest supplier to Belgium.

Canada is the largest supplier to Sweden.

Industrial Wood Pellets in Japan and South Korea

The major growth markets for the 2020’s


Japanese Industrial Wood Pellet Demand - Major Exporting Coutries
600,000
500,000
400,000
300,000
200,000
100,000
0
Canada
Vietnam
Other
Canada % of Total = 93.2%;
Vietnam % of Total = 5.0%
Canada % of Total = 87.2%;
Vietnam % of Total = 3.5%
Canada % of Total = 95.0%;
Vietnam % of Total = 2.1%
Canada % of Total = 63.0%;
Vietnam % of Total = 11.8%
Canada % of Total = 75.4%;
Vietnam % of Total = 18.0%
Canada % of Total = 71.3%;
Vietnam % of Total = 25.9%
2012
2013
2014
2015
2016
2017
source: Argus, Analysis by FutureMetrics


South Korea Industrial Wood Pellet Demand - Major Exporting Countries
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Canada
Vietnam
Indonesia
Malaysia
Russia
Thailand
27%
44%
66%
75%
75%
67%
2012
2013
2014
2015
2016
2017

Through 2017, the US has not been a significant participant in the NE Asian markets.

That is expected to change…

US Exports (metric tonnes) to:	2012	2013	2014	2015	2016	2017
Japan	233	326	563	237	306	316
S. Korea	184	32,018	61,977	18,847	175	10,615

Source: Argus, March 2018

Japan

Growth in Japan is expected to be strong.

Japanese buyers care about long-term contracts, rule of law, and sustainability.

<u>Policy in Japan will support major growth.</u>

FutureMetrics has a comprehensive report on Japanese pellet markets.
The report contains information on policy, IPP's, and major utilities that FutureMetrics has gathered that is unavailable anywhere else.

Japan

Biomass demand in Japan is primarily driven by three policy components:

- The Feed in Tariff (FiT) support scheme for renewable energy
- Coal thermal plant efficiency standards
- Carbon emissions targets

The only policy instrument that provides a monetary incentive is the FiT.

Minimum Efficiency Requirements

In 2016, METI released a paper from its Working Group on Thermal Power Generation describing efficiency standards for thermal plants. The paper develops standards based on “Best Available Technology” (BAT) that is economically viable for various types of fuel. The standards presented in the paper are 41% design efficiency for coal plants.

Thermal Power Plant Efficiency Calculation

$$efficiency = \frac{power\ output\ (MWh)}{fuel\ input\ (MWh)} \qquad 35\% = \frac{35\ MWh}{100\ MWh}$$

Coal Plant Efficiency Calculation with Biomass Co-Firing Deduction

$$efficiency = \frac{power\ output\ (MWh)}{coal\ input\ (MWh) - pellet\ input\ (MWh)} \qquad 41.2\% = \frac{35\ MWh}{100\ MWh - 15\ MWh}$$

http://www.meti.go.jp/committee/sougouenergy/shoene_shinene/sho_ene/karyoku/pdf/report01_01.pdf

Estimate of Pellet Demand to Meet Minimum Efficiency Requirements

Type of Power Station	Share of Coal Generation	Output (GWh/year)	Actual Efficiency	Coal Consumption (Tonnes/year)	Target Efficiency	Co-firing needed get to Target	Wood Pellets required (Tonnes/year)
Ultra Super-Critical	60.12%	134,600	41.5%	44,938,500			-
Super-Critical	27.82%	62,300	39.9%	21,649,800	41.00%	2.71%	899,520
Sub-Critical	12.06%	27,000	37.7%	9,927,800	41.00%	8.05%	1,226,264
	100.00%	223,900	40.61%	76,516,100	41.00%		2,125,784

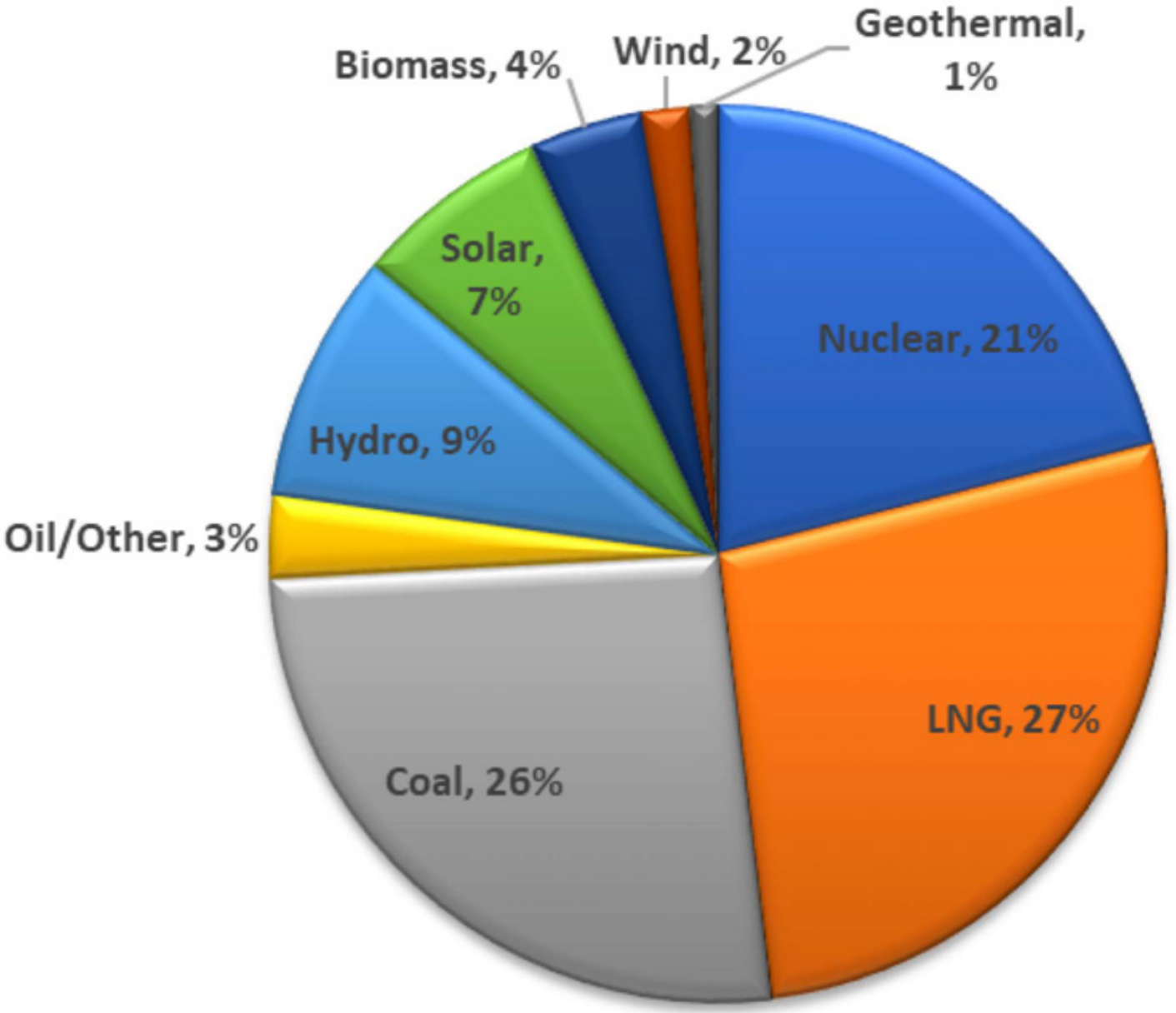
source: data from Japan Federation of Electric Power Companies, Analysis by FutureMetri

GHG Emission Reduction Targets, the Paris Climate Accord, and Japan's "Best Energy Mix"

In 2015, the 21st annual Conference of Parties (COP21) of the UN Framework Convention on Climate Change (UNFCCC) was held in Paris, France. The conference resulted in the treaty that has become known as the Paris Climate Accord.

Japan's INDC ("Intended Nationally Determined Contributions") calls for a 26% reduction in GHG emissions by fiscal year (FY) 2030 compared to FY 2005. Japan's INDC also states that its energy mix will consist of 22-24% renewable energy by FY 2030.

Japan's "Best Energy Mix" for 2030



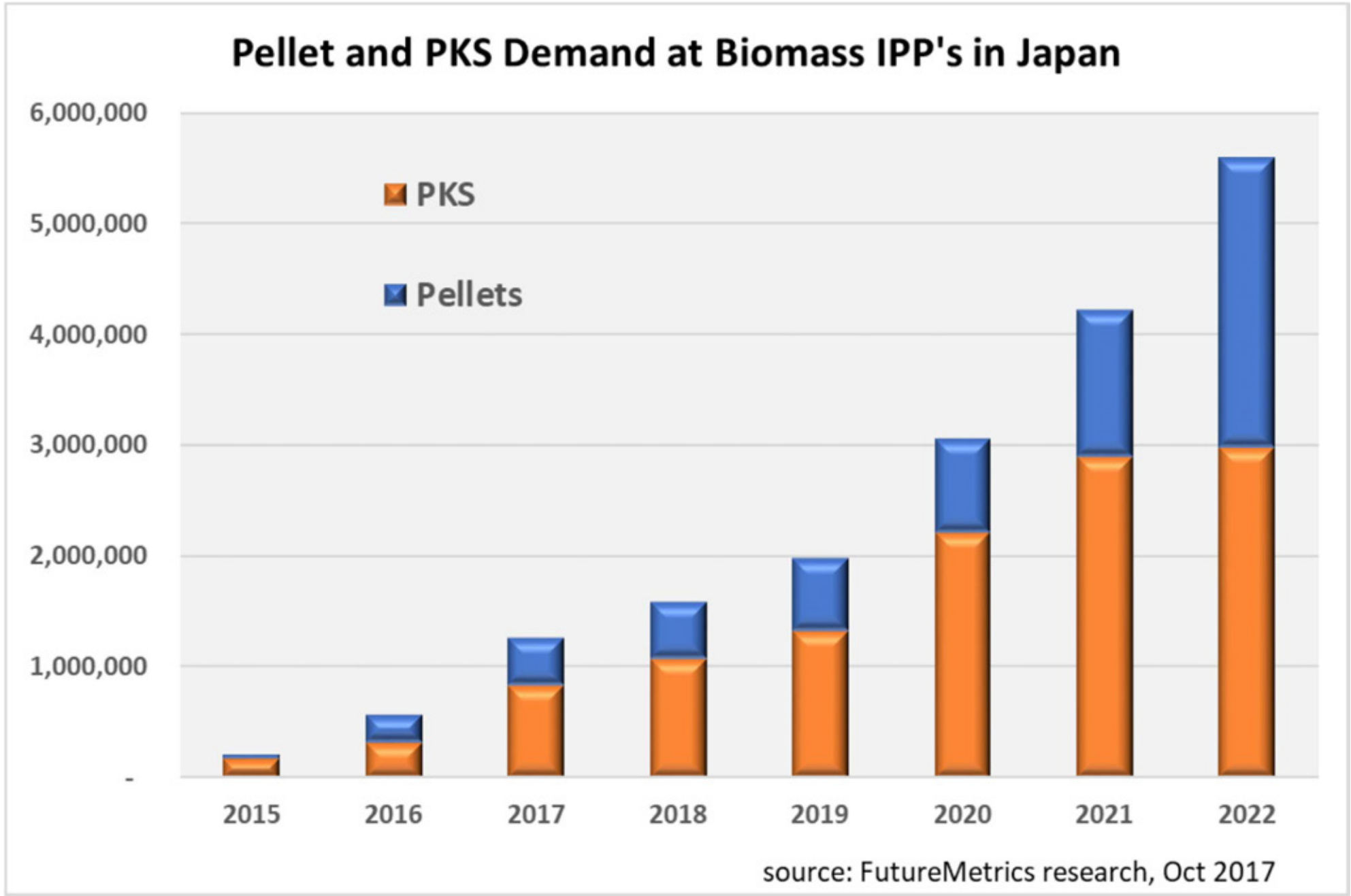
Best Energy Mix

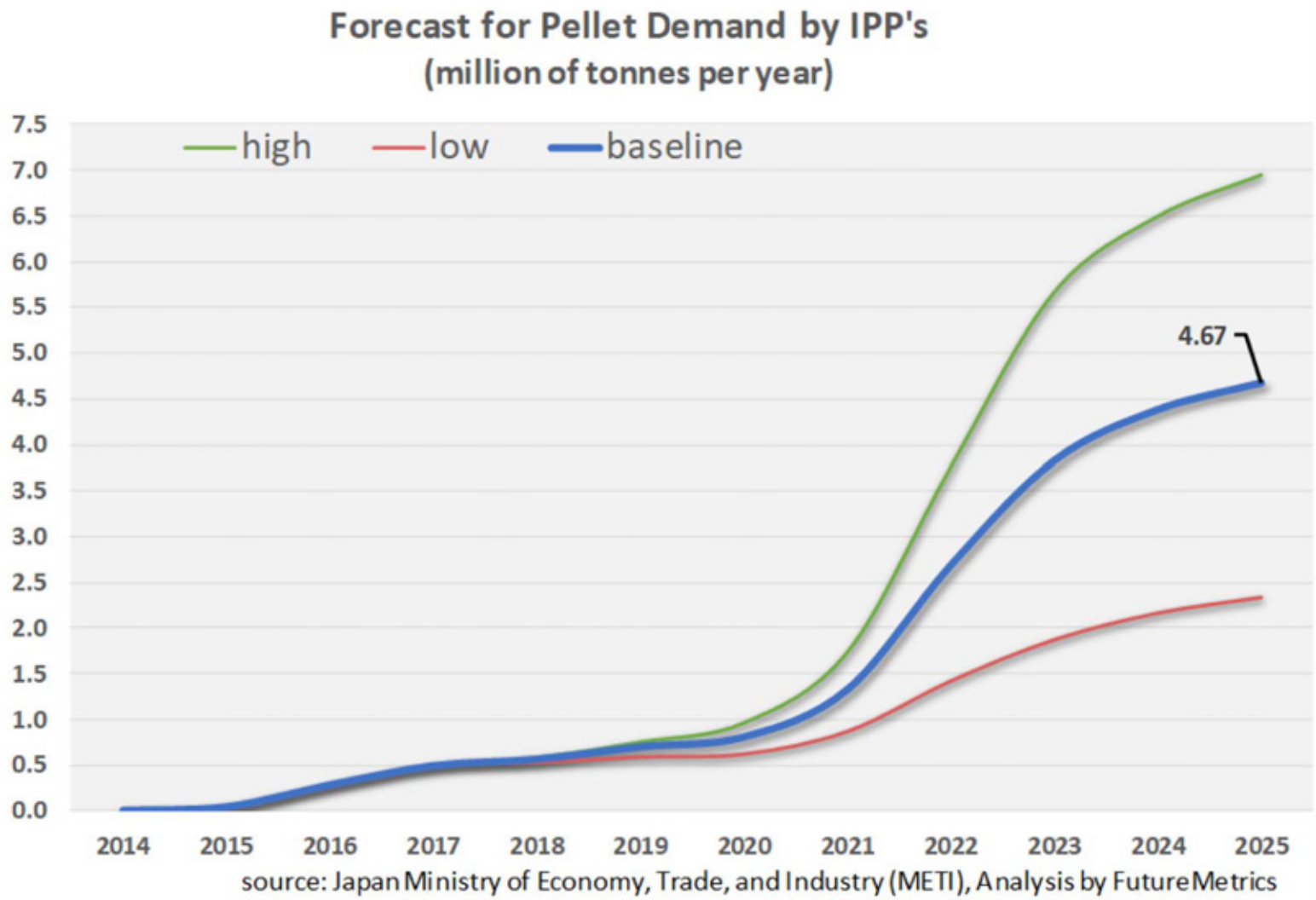
Based on 1,065 Million MWh's of Demand in 2030	Energy Mix	Millions of MWh's
Renewable	23%	244.95
Nuclear	21%	223.65
LNG	27%	287.55
Coal	26%	276.90
Oil	3%	31.95
TOTALS	100%	1,065.00

Renewable Portion	Energy Mix	Millions of MWh's	Capacity Factor	Nameplate MW's Needed
Geothermal	1.0%	10.65	90%	1,351
Biomass	4.3%	45.80	85%	6,150
Wind	1.7%	18.11	30%	6,889
Solar	7.0%	74.55	25%	34,041
Hydro	9.0%	95.85	90%	12,158
	23.0%	244.95		60,589

If 30% of the biomass portion is produced from pellets:
<u>Pellet demand will be about 7.8 million tonnes per year.</u>

The IPP's will drive substantial growth in demand for biomass.





The chart is based on analysis of about 140 IPP's by FutureMetrics

Total potential demand in Japan from utility power plants and from IPP's could exceed 12 million tonnes per year by 2025.

S. Korea

Growth in South Korea is expected to be strong
(but there is tangible uncertainty!).

S. Korean buyers, to date, have not engaged in long-term offtake deals.

The lowest cost for delivered pellets and frequent competition for short-term supply contracts is the norm.

<u>Policy in S. Korea is supporting major growth right now!</u>

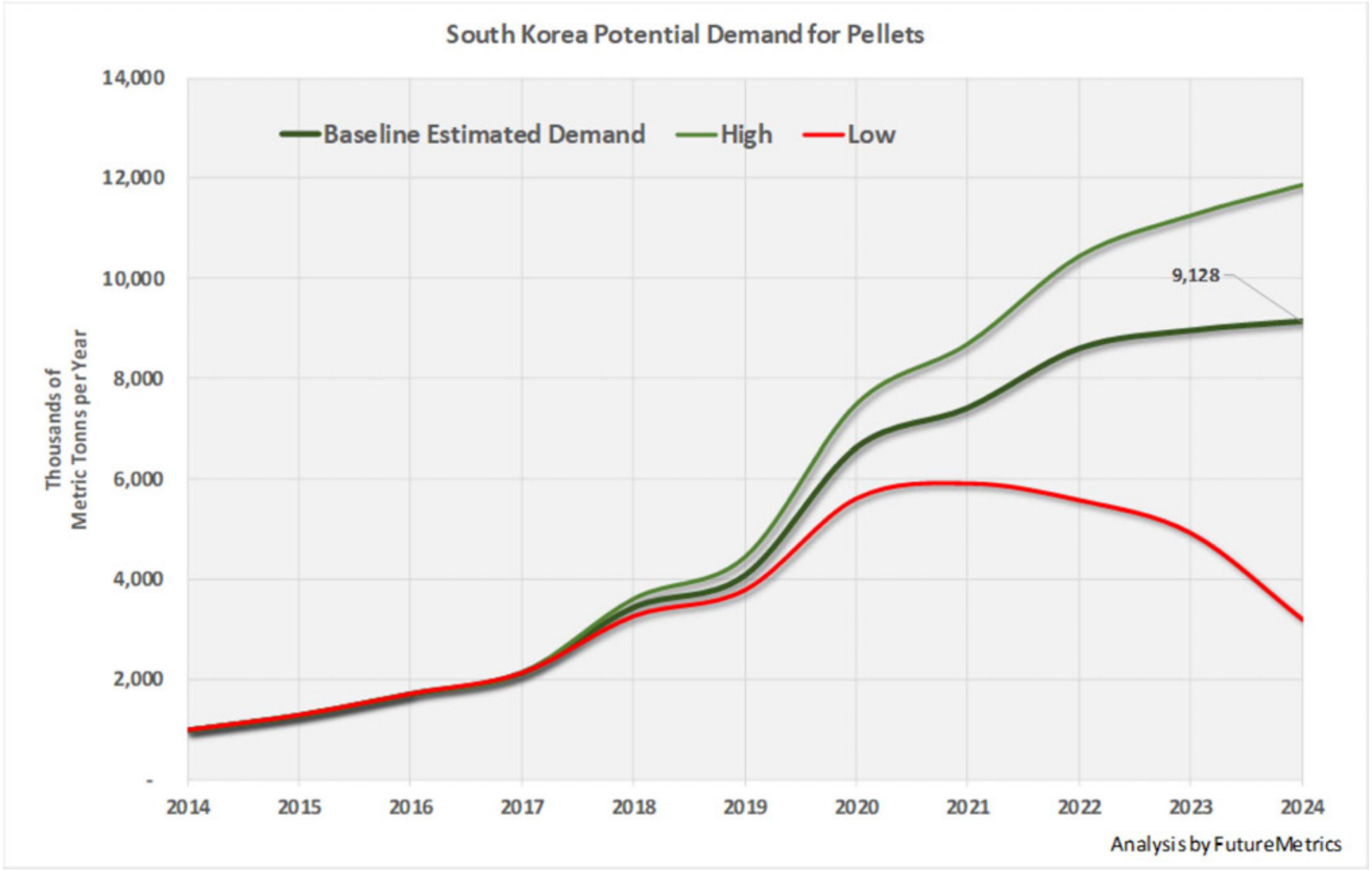
S. Korea is guiding the power generation industry with a Renewable Portfolio Standard (RPS).

The RPS program requires the 13 largest power companies (with installed power capacity larger than 500 MW) to steadily increase their renewable energy mix in total power generation over the period from 2012-2024.

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
2.0%	2.5%	3.0%	3.0%	3.5%	4.0%	4.5%	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%

Utilities must generate or buy REC's to meet their RPS obligation, or pay a fine of 150% of the average REC price for every MWh they are short of their obligation.

Based on announced co-firing or full-firing, S. Korea demand could reach about 7 million tonnes per year by 2020 and 9 million tonnes per year by 2024



But there are risks…

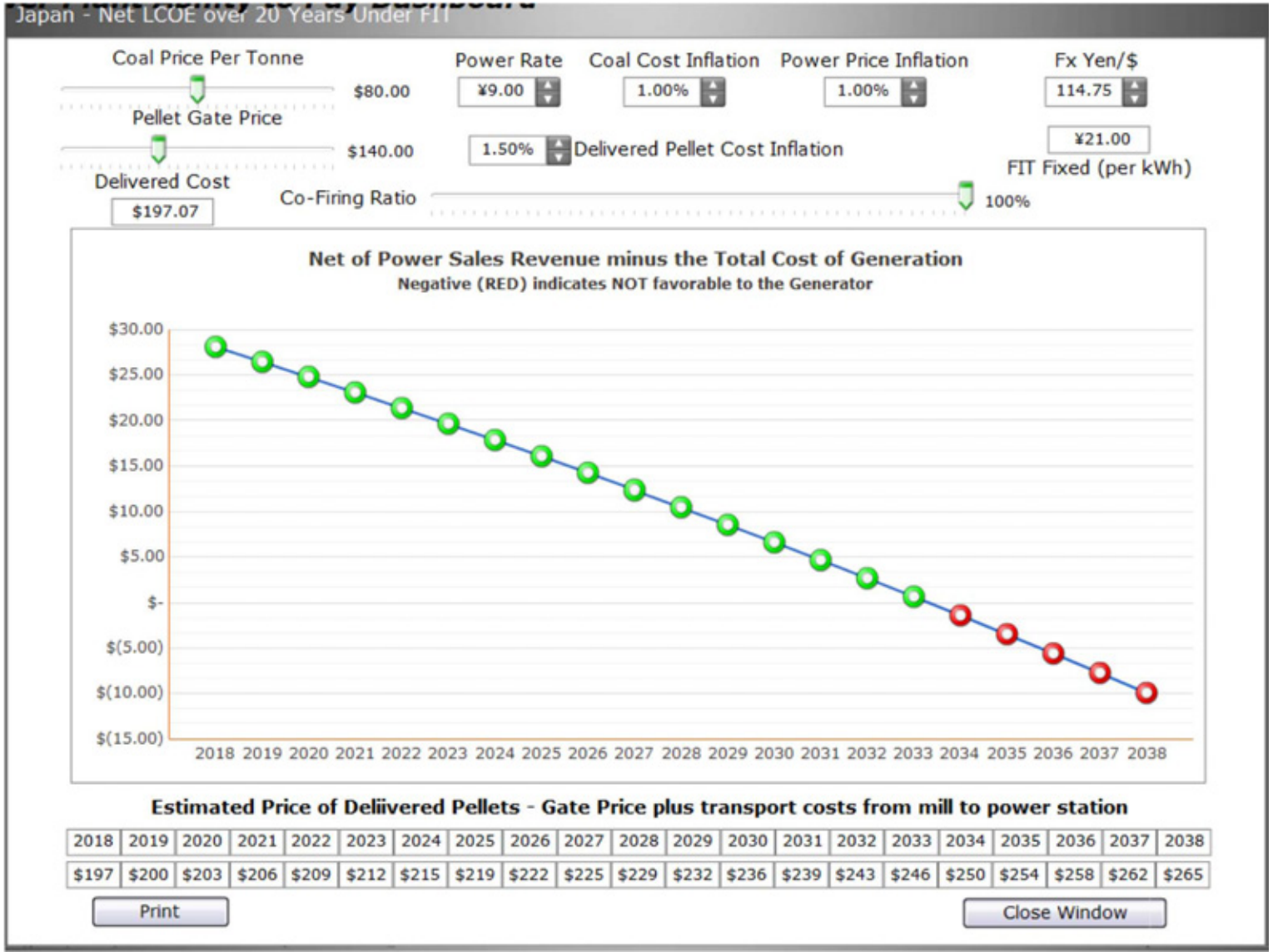
The Japanese FiT is fixed for 20 years.

There is no adjustment for inflation.

Thus the long-term offtake deals have to recognize the fixed top-line revenue from the FiT.

If the starting price of pellets in the offtake deal is too high and/or the annual adjustment is too high, the utility will reach a point in time when costs are higher than revenue.

There are many scenarios. The example below is for a plant using 100% pellets.
Given a pellet gate price of $140/MT and total logistics costs of about $57 (delivered to power plant at about $197/MT in year one of the offtake deal), and an annual adjustment in the price of pellets of 1.5%,
the generator goes into the red in 2033 (17 years in to the deal).



The generator is very profitable in the early years (about $30/MWh in 2018) **but that margin shrinks as fuel prices go up while the top line revenue from the FIT remains constant**.

FX risk, inflation risk, and logistics cost risk have to be managed.

Note that at 100% pellets the inputs for coal and wholesale power prices are not relevant to the analysis.

At the end of 2017, METI announced that it was planning to stop offering a fixed price for biomass electricity generation and instead auction off biomass contracts under a tender system starting in FY 2018 (April 1, 2018).

This does not impact the 16 GW of biomass capacity that has already received approval for FiT.

However, some of the approved projects will never be built.

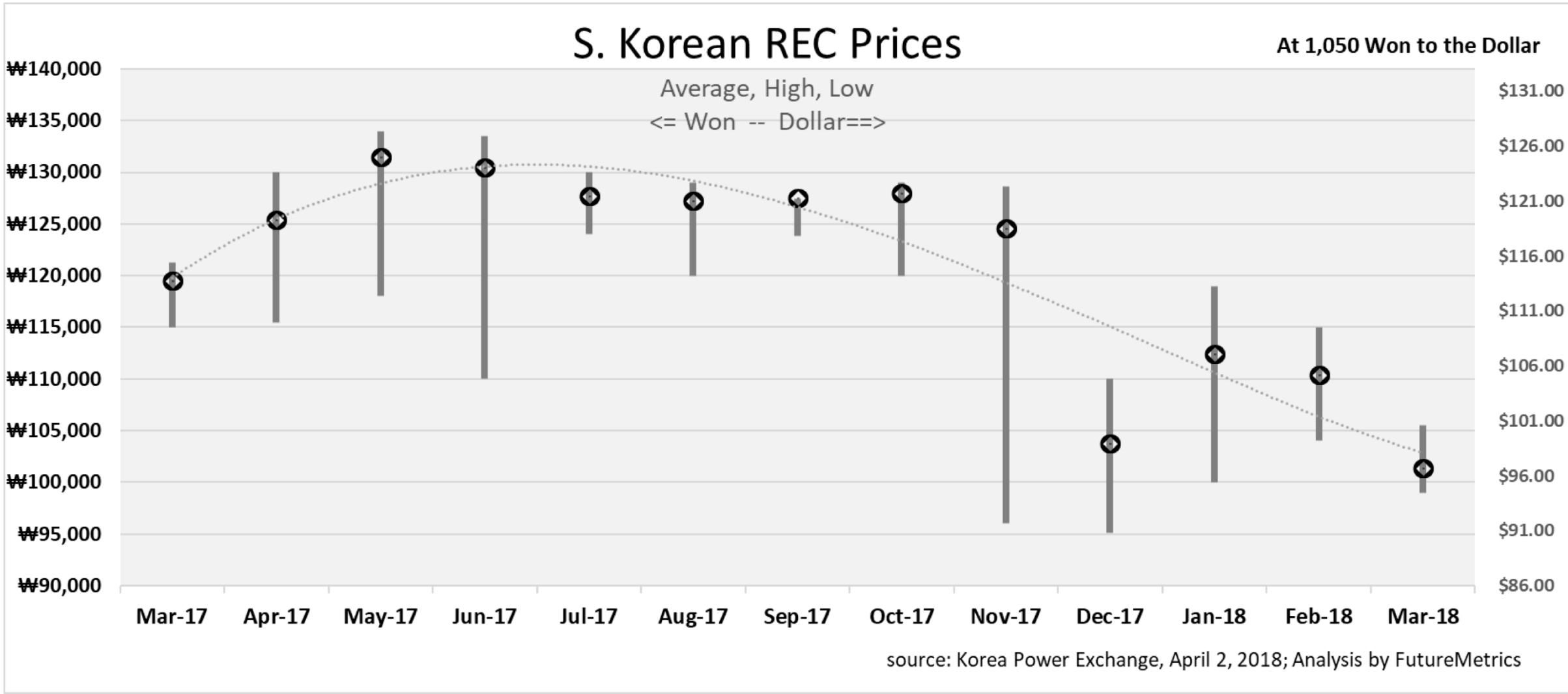
About 50% of “general wood” projects, representing 40% of output capacity, plan to use palm oil, which is not what the policy had originally intended and will likely not meet the soon to be announced sustainability requirements.

Many projects are based on “domestic biomass”. There is insufficient domestic biomass to provision a significant proportion of FiT approved projects based on domestic biomass!

The S. Korean RPS is based on REC's.

The price of REC's is determined by the supply and demand for REC's.

There is currently excess demand for REC's and REC prices have been very favorable to the genco's.


S. Korean REC Prices
At 1,050 Won to the Dollar
Average, High, Low
<= Won -- Dollar==>
₩140,000
₩135,000
₩130,000
₩125,000
₩120,000
₩115,000
₩110,000
₩105,000
₩100,000
₩95,000
₩90,000
$131.00
$126.00
$121.00
$116.00
$111.00
$106.00
$101.00
$96.00
$91.00
$86.00
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
source: Korea Power Exchange, April 2, 2018; Analysis by FutureMetrics

The generators currently receive 1.5 REC's per MWh of power generated from pellets.

REC's have traded between ₩125,000 ₩130,000 for many months in 2017.

At ₩130,000 , for every MWh generated from pellets, REC revenue is ~$185*!!

At the most recent average (March 2018) REC price of ₩101,250, the REC revenue is ~$144*.

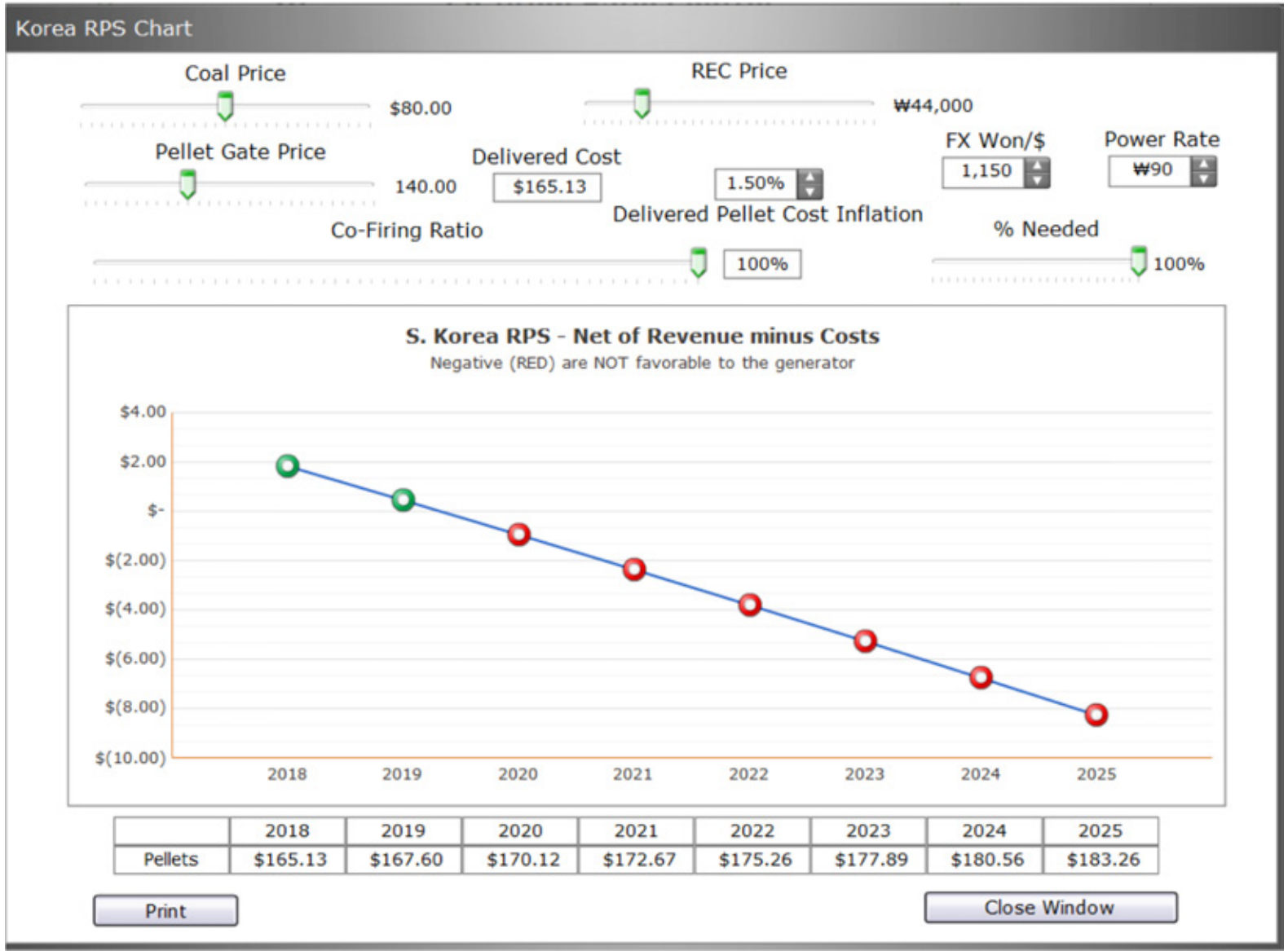
South Korea is expected to change the RECs per MWh from 1.5 to 1.0.

At March REC prices that would equate to REC revenue of ~$96.

*FX at 1,050 won per dollar.

It is no surprise that S. Korean generators are rushing into co-firing and full-firing. At a REC price of ₩130,000, and current prices for Vietnam pellets, the profits are around $118 per MWh!!

However, if REC prices fall to low, the generator will lose money using pellets for fuel.



In this example, if REC prices fall to ₩44,000 (about $42), the generators goes into the red in 2020.

If the losses are large enough, **the generator is better off burning 100% coal** and paying the fine of 1.5 times the average REC price.

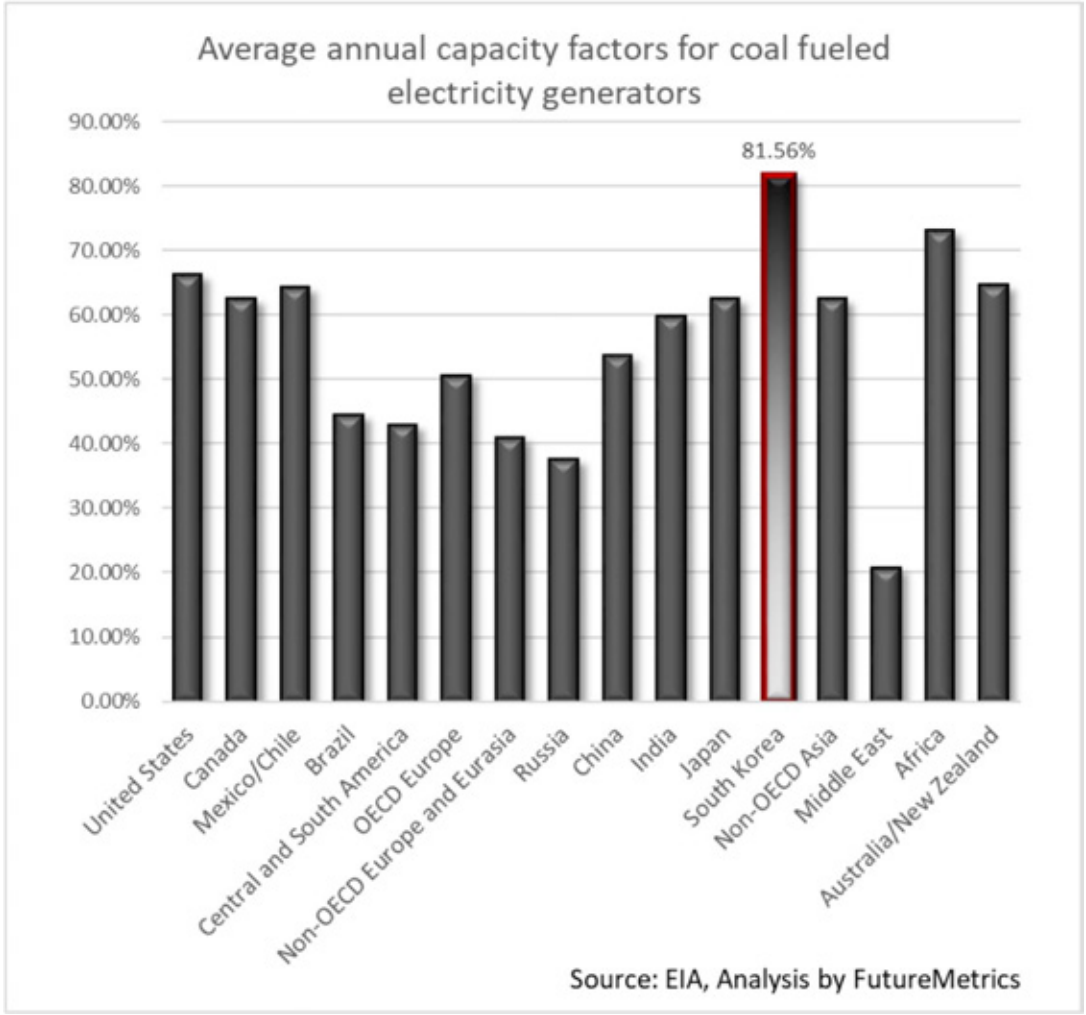
Given the uncertainty of future REC prices and the REC/MWh multiplier, it is rational for South Korean utilities to avoid long-term take or pay offtake deals at prices that are typical for most producers.

Which raises the question:

How will S. Korea procure so many millions of tonnes with no long-term offtake agreements?

Producers will not build capacity to match that demand without long-term agreements to buy the pellets.

S. Korea has a high dependence on pulverized coal generated baseload power. So if RPS requirement are to be satisfied, replacing coal with pellets is necessary.



<u>FutureMetrics thinks that policy will evolve… Question is, HOW?</u>

Black Pellets?

Are Black Pellets Ready to Compete in the Industrial Wood Pellet Sector?

Advanced, wood pellets, often called “black pellets” due to their appearance after thermal treatment, have long been touted as a superior fuel to conventional “white” wood pellets.

Black pellets are supposed to address some of the potential shortcomings associated with white wood pellets for use as a substitute for coal in pulverized coal power plants.

Black pellets, generally refer to two distinct technological approaches to developing an advanced wood pellet: torrefaction and steam explosion (SE).

Torrefaction is a form of pyrolysis that results in partial thermal decomposition in the absence of oxygen. Typically, torrefaction is conducted between 200˚C and 300˚C to remove volatiles from the wood, the resultant material is then densified into pellets.

FutureMetrics has **not** analyzed in detail any of the torrefaction technologies.

FutureMetrics has analyzed, in detail, the Arbaflame* technology for producing SE pellets.

*FutureMetrics has been given full access to the Arbaflame intellectual property and their 40,000 tonnes per year SE pellet plant in Norway. FutureMetrics is not engaged with Arbaflame in any way. The FutureMetrics report that this presentation is based on is an independent analysis of the Arbaflame technology. Arbaflame has granted FutureMetrics permission to publish the information in this presentation.

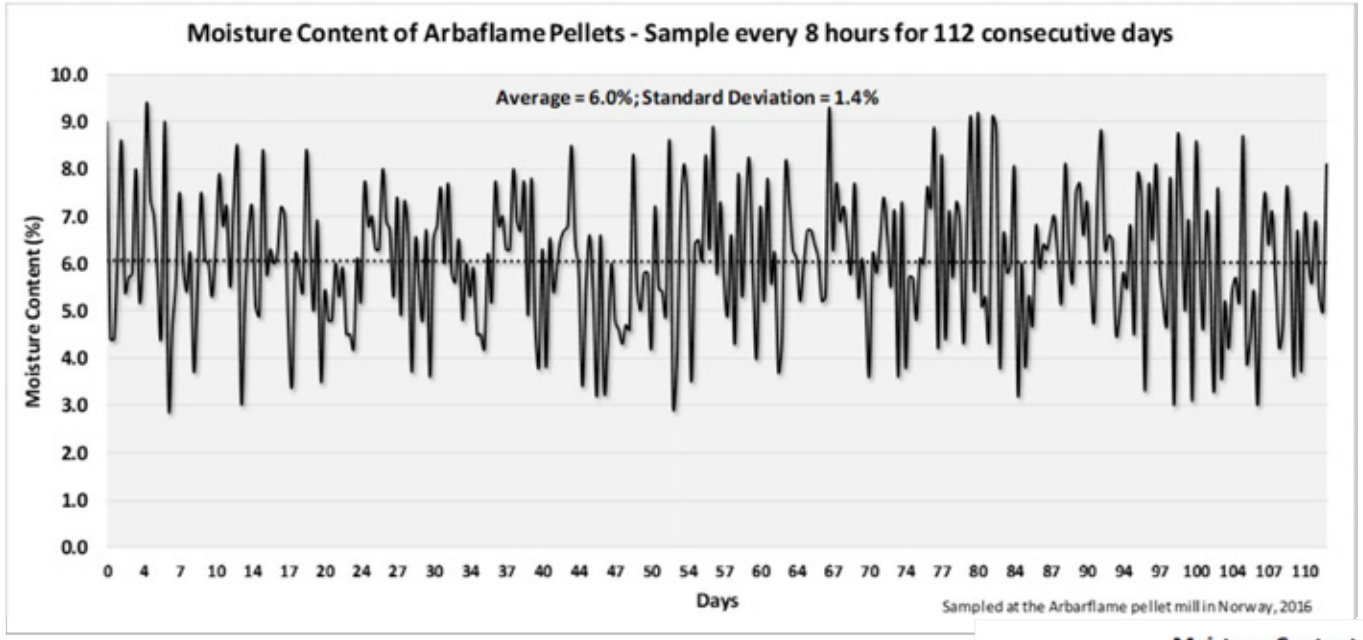
Several advantages of SE pellets are:

- In contrast to white pellets, SE pellets will not disintegrate when they get wet.
- SE pellets have a higher volumetric and gravimetric energy density than white pellets (~31% more GJ/m^3). This means more energy can be stored or transported per unit of volume.
- SE pellets are hard and durable and produce significantly less dust (fines) when handled.
- Power requirements for pulverizing SE pellets at the pulverized coal power station are significantly lower than the power requirements for pulverizing white pellets.

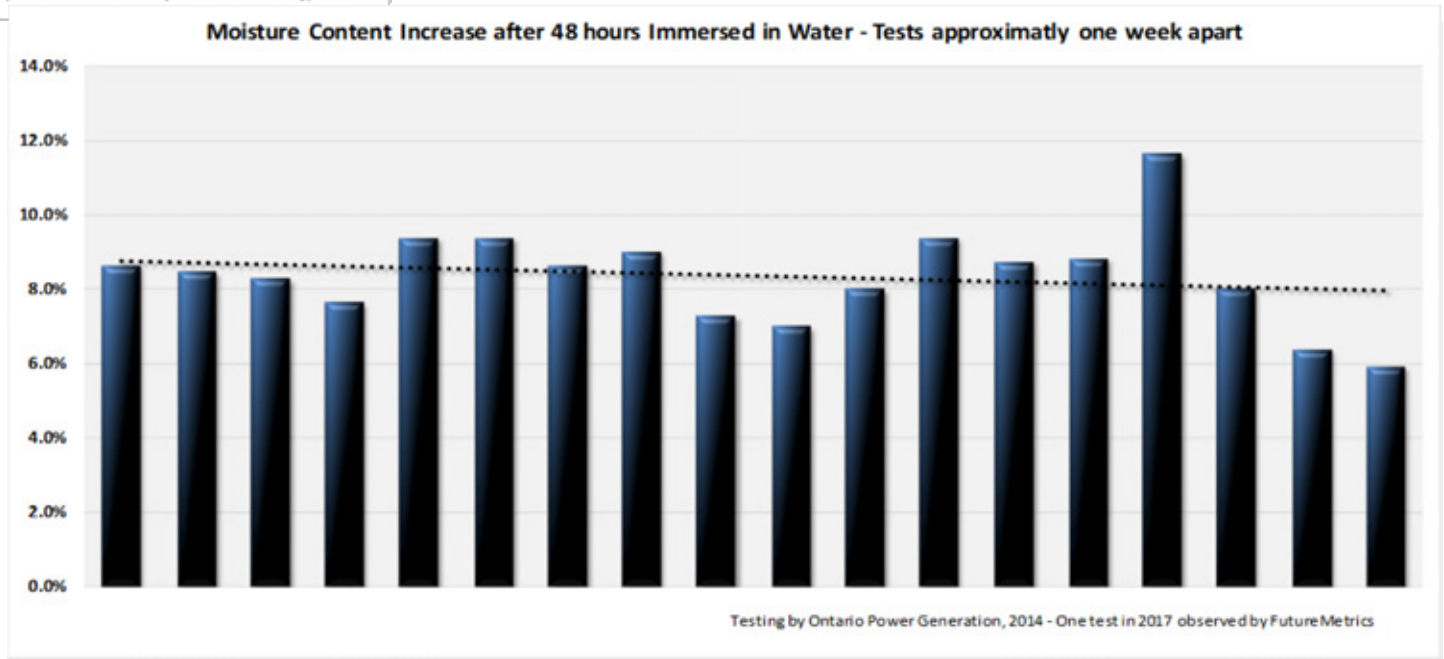
The steam explosion process causes the lignin to emerge on the surface of the fine wood fibers in the form of small beads.

These beads, when the fiber is densified in the pellet press, form a film-like surface coating on the broken-down wood fibers and results in hard, highly water-resistant pellets that produce almost no dust (fines).

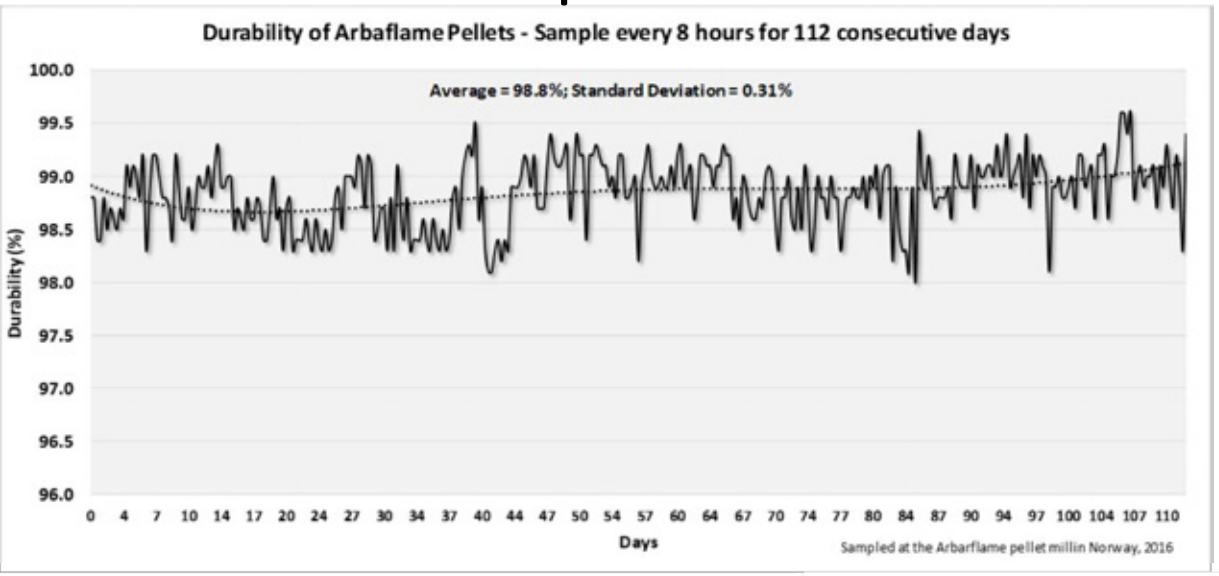
Impact of Water on Moisture Content and Durability

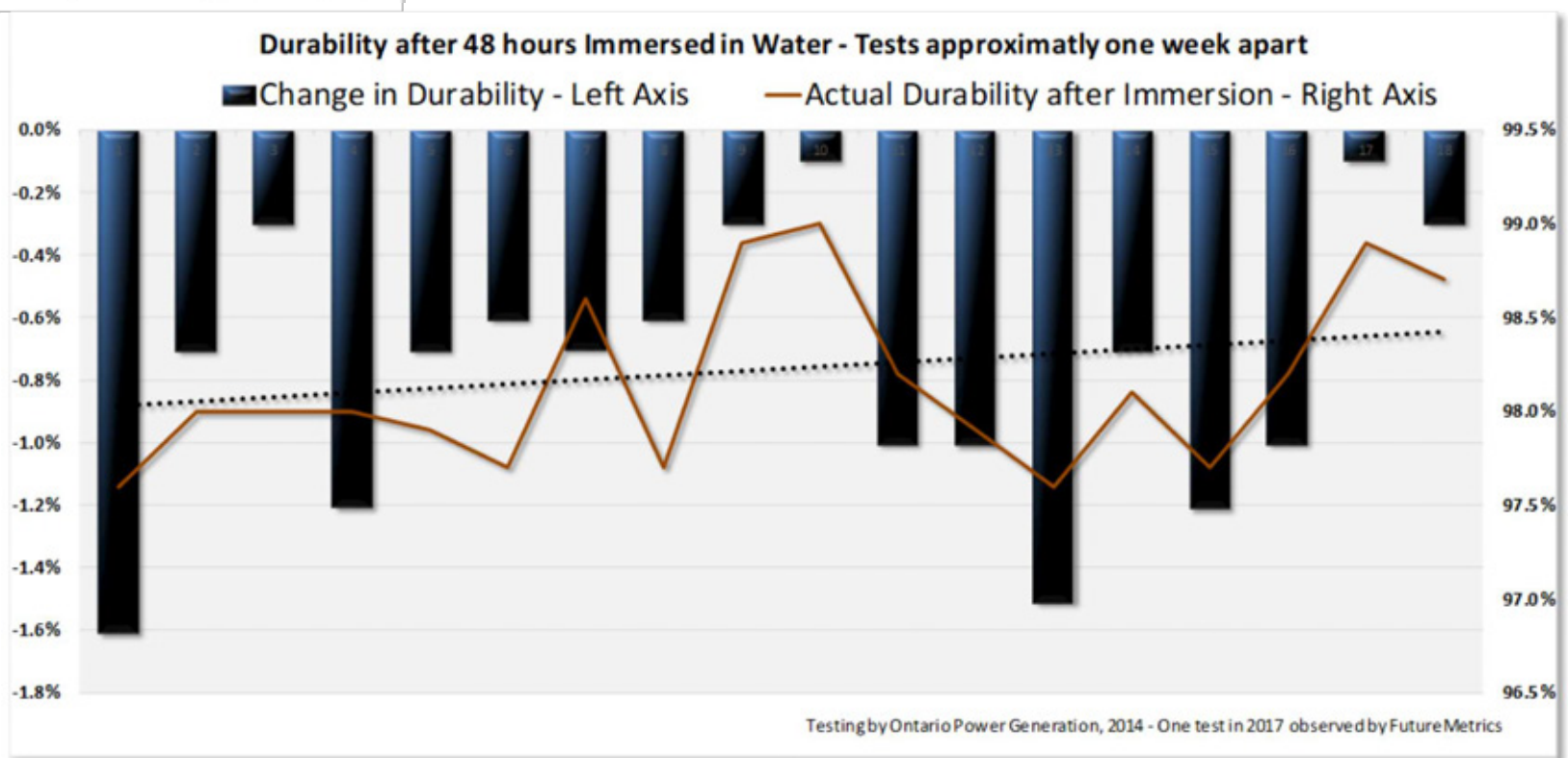


After 48 hours of immersion the water uptake is ~8%, and the change in durability is -0.7%, from an average of 98.9% to an average of 98.2%. If the pellets are then dried in the open air, they return to their original MC and durability.



Impact of Water on Moisture Content and Durability

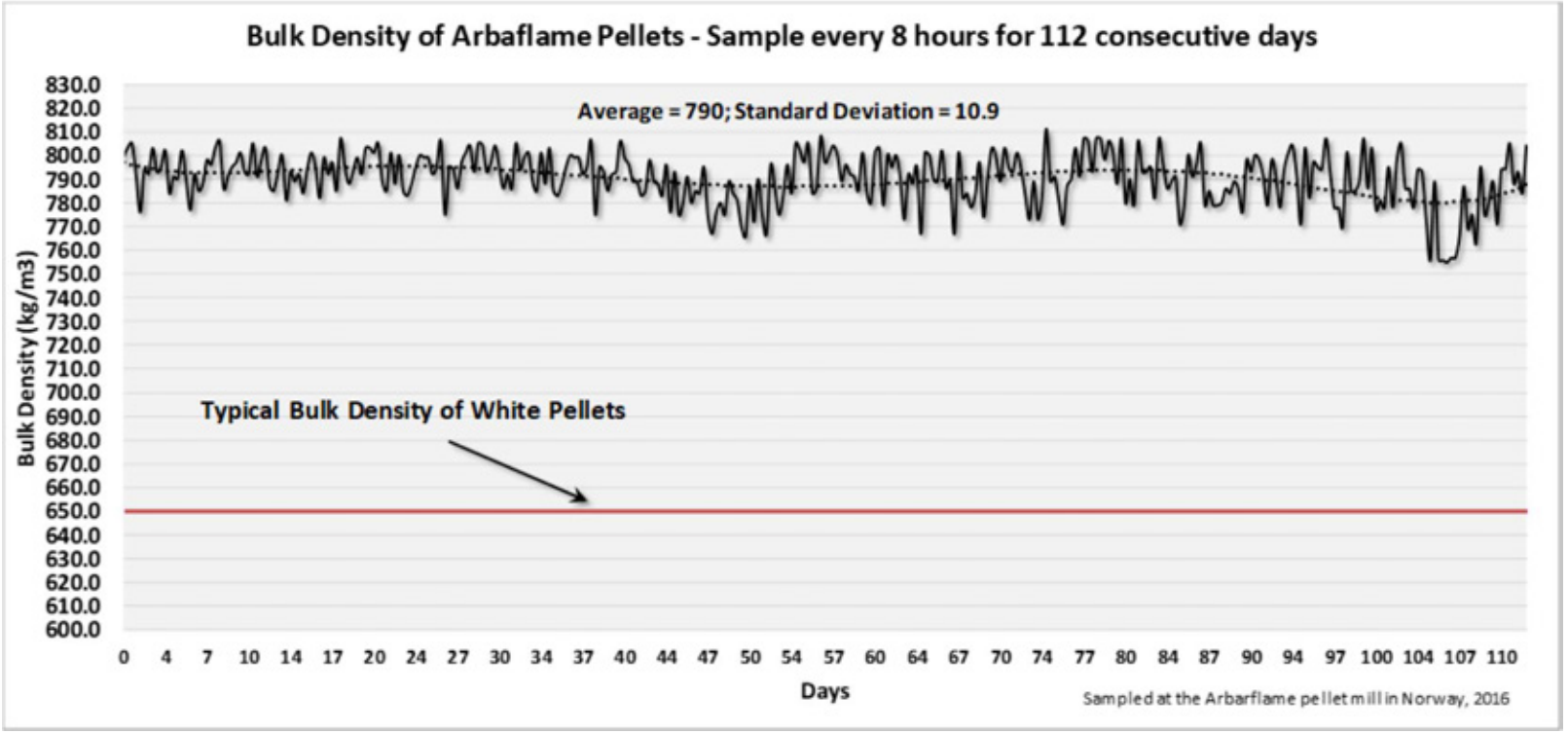




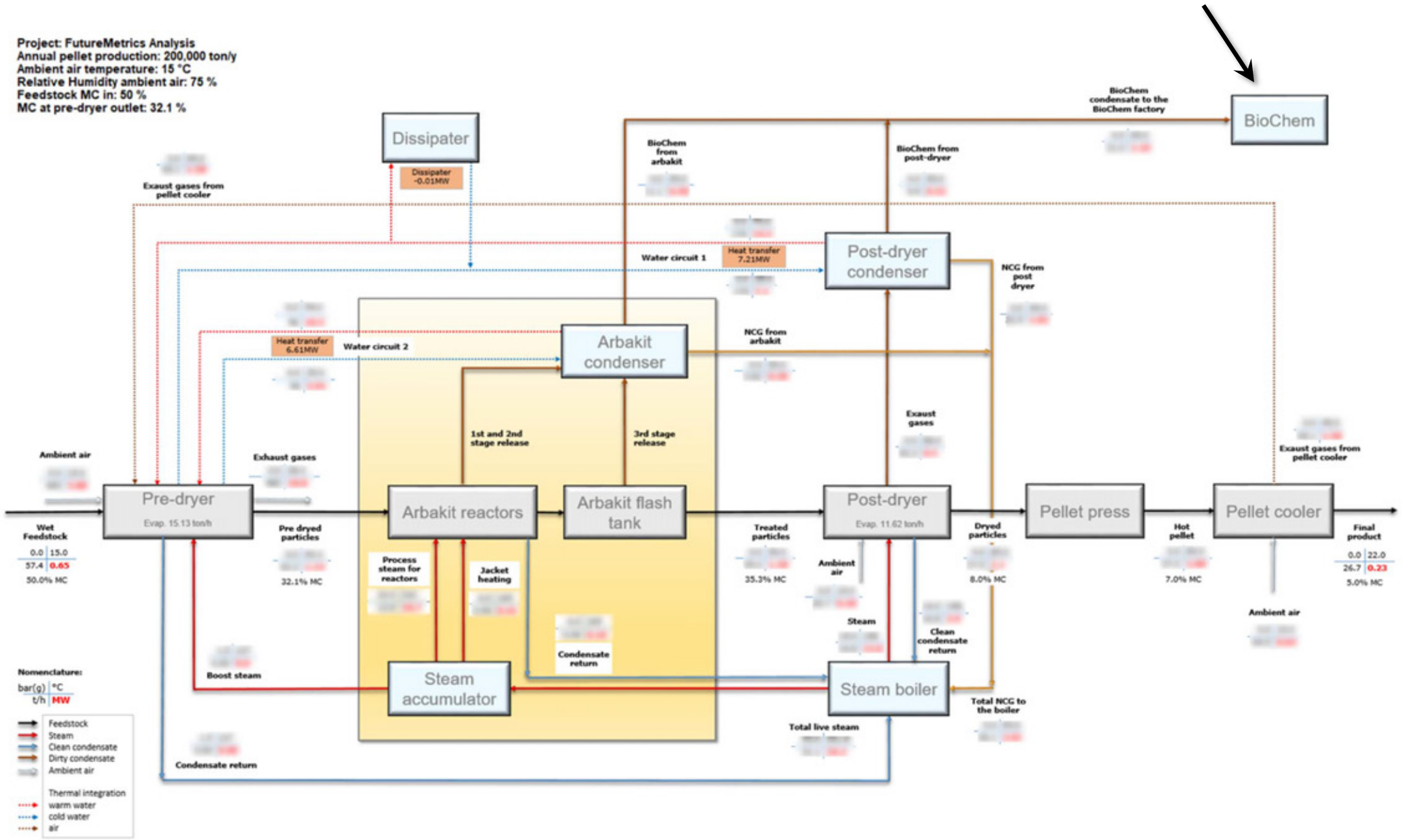
Impact of Higher Gigajoules per Cubic Meter

The impact of higher specific energy content in GJ/tonne (about 19.5 for SE and about 17.5 for white) and bulk density (about 790 kg/m^3 for SE versus about 650 kg/m^3 for white) on transportation costs per GJ delivered is another characteristic of SE pellets that gives them an advantage over white pellets.

A fully loaded 60,000 cubic meter vessel will carry about 682,000 GJ of energy with white pellets and about 924,000 GJ of energy with SE pellets.



Highly Optimized Process – Energy is Not Wasted – Plus BioChem



Example of FutureMetrics' Model for Estimating Steam Demand and Fuel Cost

(The table is broken into two parts to fit on the page)

MC	pre dry optimum	air temp	wet feed stock	Steam treatment input	Steam treatment reclaim	Post Dry Input	Post dry reclaim	Pellet dryer reclaim	Net boiler load	Gross steam demand	Dissipate (-) / Boost(+)	Heat wet feed stock to exit temp
%	% MC	°C	t/hr	MW	MW	MW			MW	MW	MW	MW
45.00%	30.10%	13	52.48	11.10	6.64	8.13	6.56	1.54	19.23		-2.78	0.99

Evap H2O	Ambient air requirement	Pre dryer Air Exit	Pre dryer Particle Exit	Heat air to pre - dryer exit temp	Pre dry energy need	Required green fuel	Required green fuel	fuel $/yr	Fuel cost	Ex works cost
MW	t/hr	°C	°C	MW	MW	t/hr	t/yr		$/tonne pellets	$/tonne of pellets
10.35	313.00	36.70	41.70	2.10	13.45	7.76	57,785	794,540	3.97	$112.96

FutureMetrics believes that the Arbaflame SE pellet technology has overcome the technical shortcomings that have prevented the production of cost competitive SE pellets.

The ability to provide fuel delivery security to newly-built pellet fueled power plants and converted/modified existing plant for co-firing or full-firing is critical.

The white pellet sector has multiple production plants in numerous locations. If there is a problem at one plant or at a shipping terminal, there is redundancy across the supply chain. The SE pellet sector does not yet have that supply chain redundancy.

Based on our analysis, the only impediment to rapid growth in the SE pellet sector is that of overcoming the lack of redundancy in the fuel supply chain.

Conclusion

Global industrial wood pellet demand is expected to more than double in the next seven years from about 20,000,000 tonnes per year in 2018 to about 41,000,000 tonnes per year in 2025.

North America will continue to be a major supplier to that growing market.

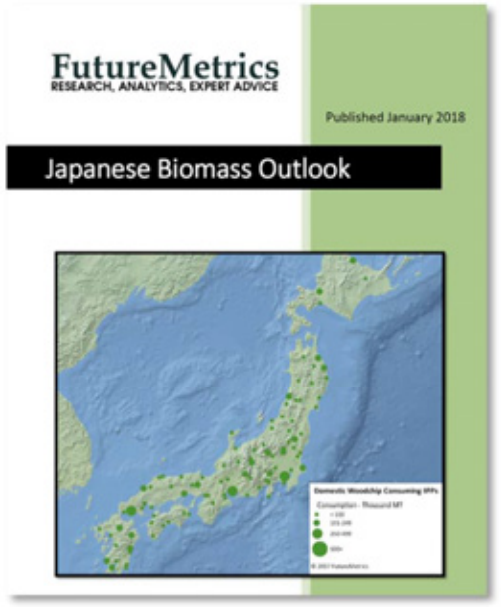
FutureMetrics forecasts that SE pellets will become a viable choice for solid fuel derived from biomass.

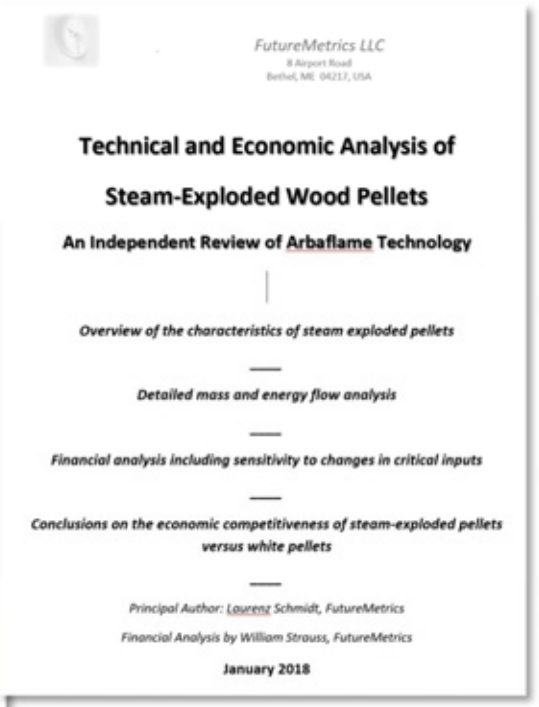
Three Recent Reports by FutureMetrics

Japan Biomass Outlook – A comprehensive report by Seth Walker that contains a detailed accounting of Japan's current and forecast demand for biomass (wood pellets, PKS, and wood chips). The report contains many details that are not available from any other source including a detailed list of nearly 150 IPP's that in the pipeline.

Independent Assessment of Arbaflame's Steam Exploded Pellet Technology and Economics – A comprehensive report by Laurenz Schmidt that contains a detailed analysis of the technology's mass and energy flows, of the characteristics of the final products, and contains an analysis of the costs to produce the final products.

North American Pellet Market Quarterly – A report contained research, analysis, and forecasts for industrial and heating markets in North America. This subscription product is published four time per year.





Thank you – Bill Strauss – WilliamStrauss@FutureMetrics.com