Wood Pellets

How a simple solid fuel is an important component of a pathway to a more decarbonized future

Presented by William Strauss, PhD
President, FutureMetrics

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

Award Winning and Well-Respected FutureMetrics Team Members

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 transatlantic shipment of wood pellets from North America to Europe (1998). Leading expert on pellet plant operations.

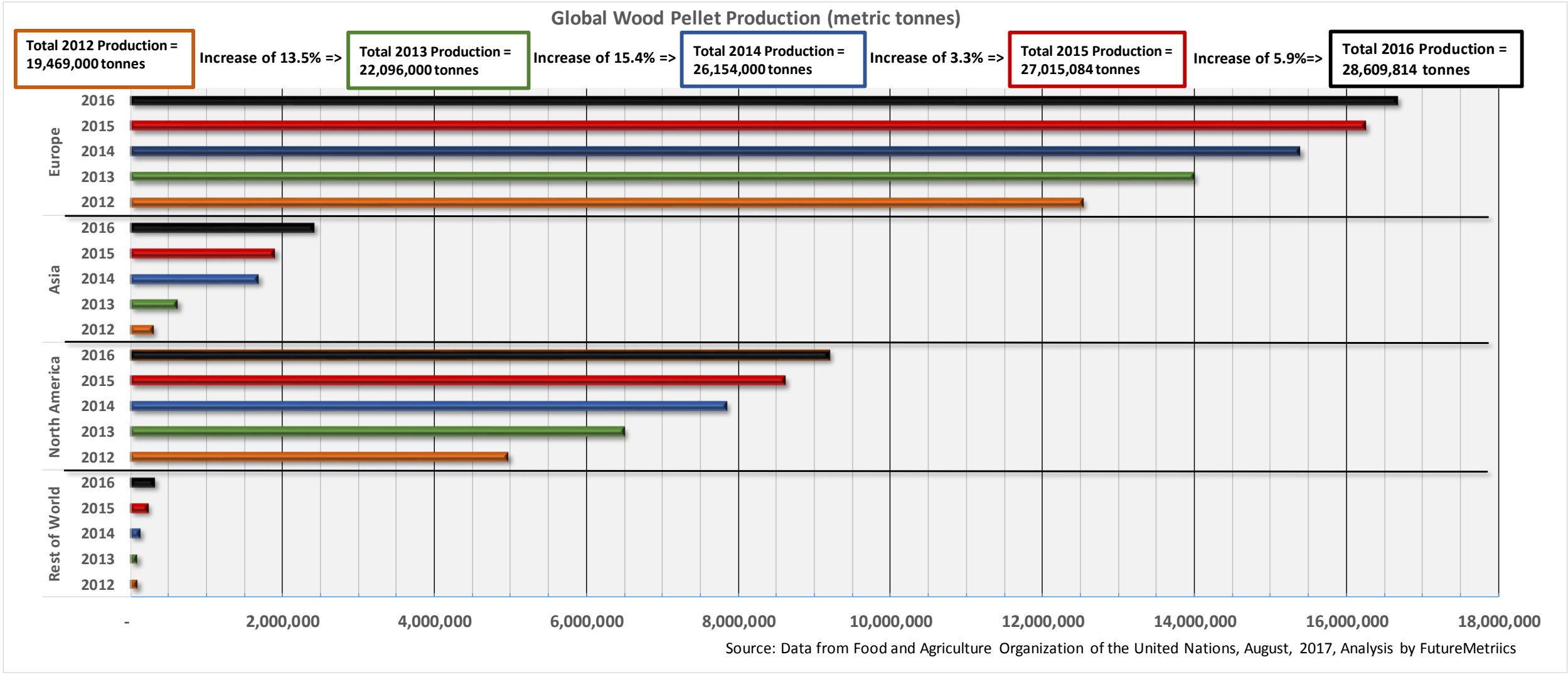
Seth Walker, Senior Economist

A leading and often cited researcher, analyst, and author in the wood pellet sector.

Has presented at dozens of conferences throughout the world.

Overview of Global Pellet Markets

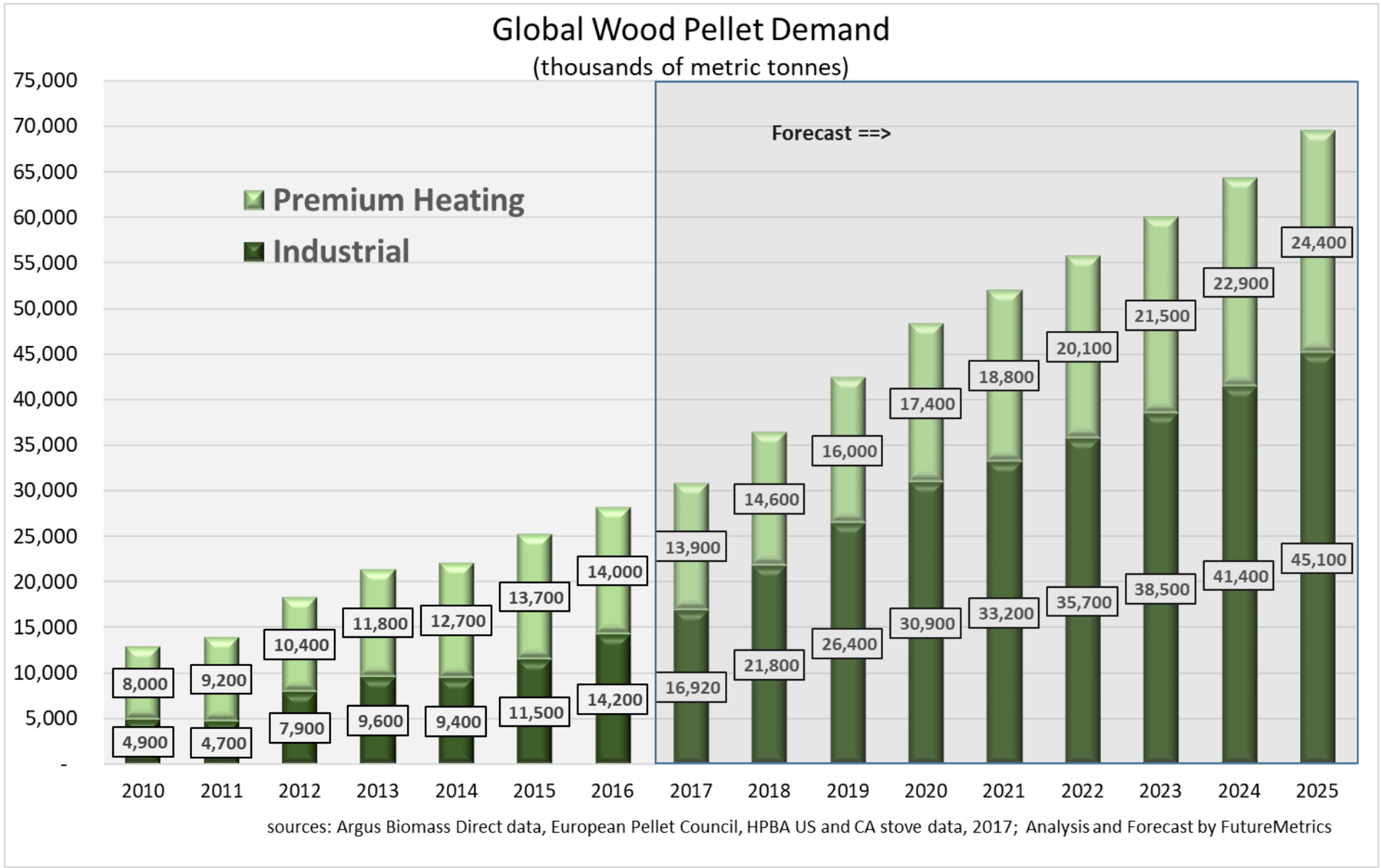
The wood pellet markets have experienced growth rates over the last few years of about 10% annually:
from about 19.5 million tonnes in 2012 to about 28.6 million tonnes in 2016.



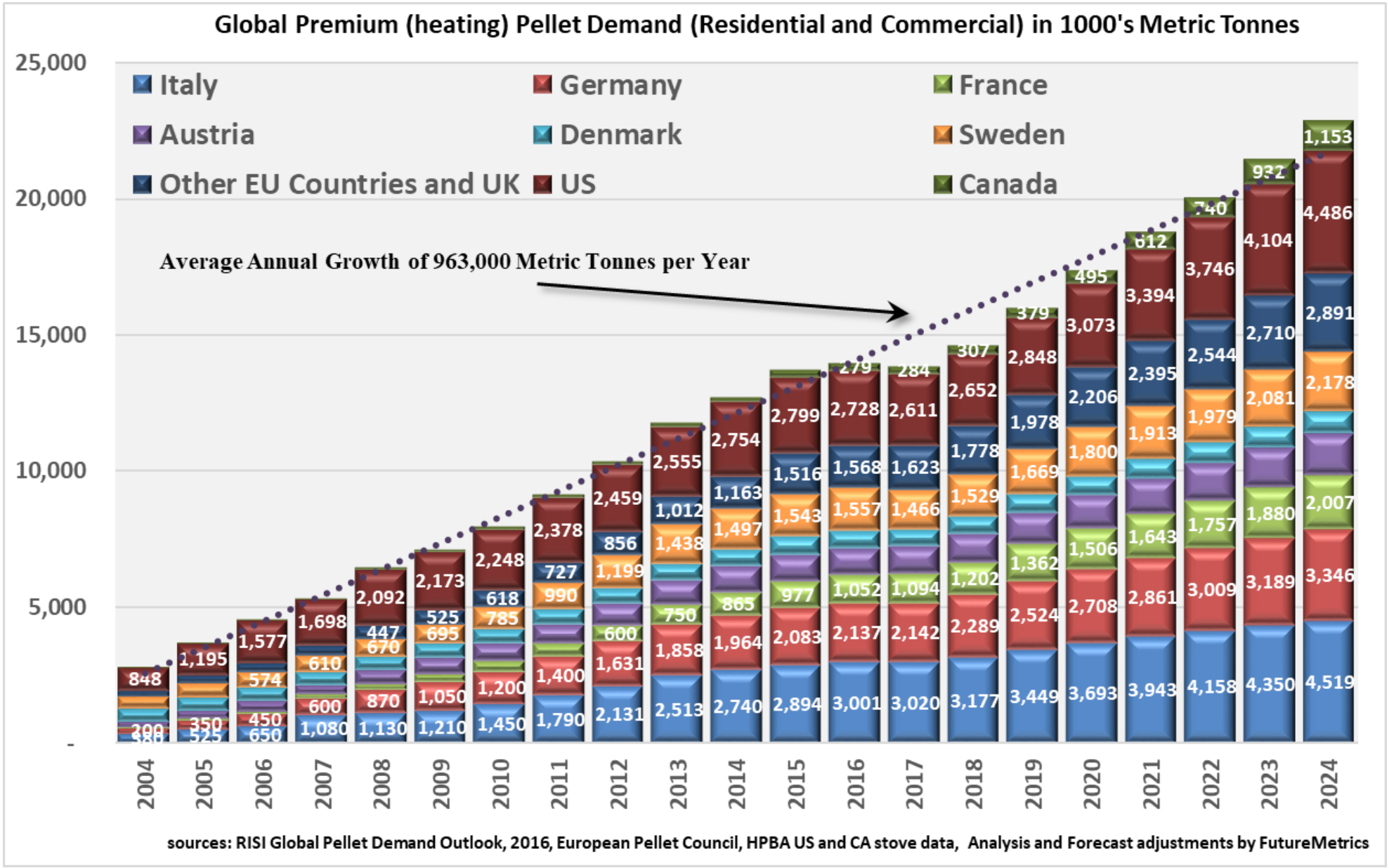
There are two major markets for pellets:

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

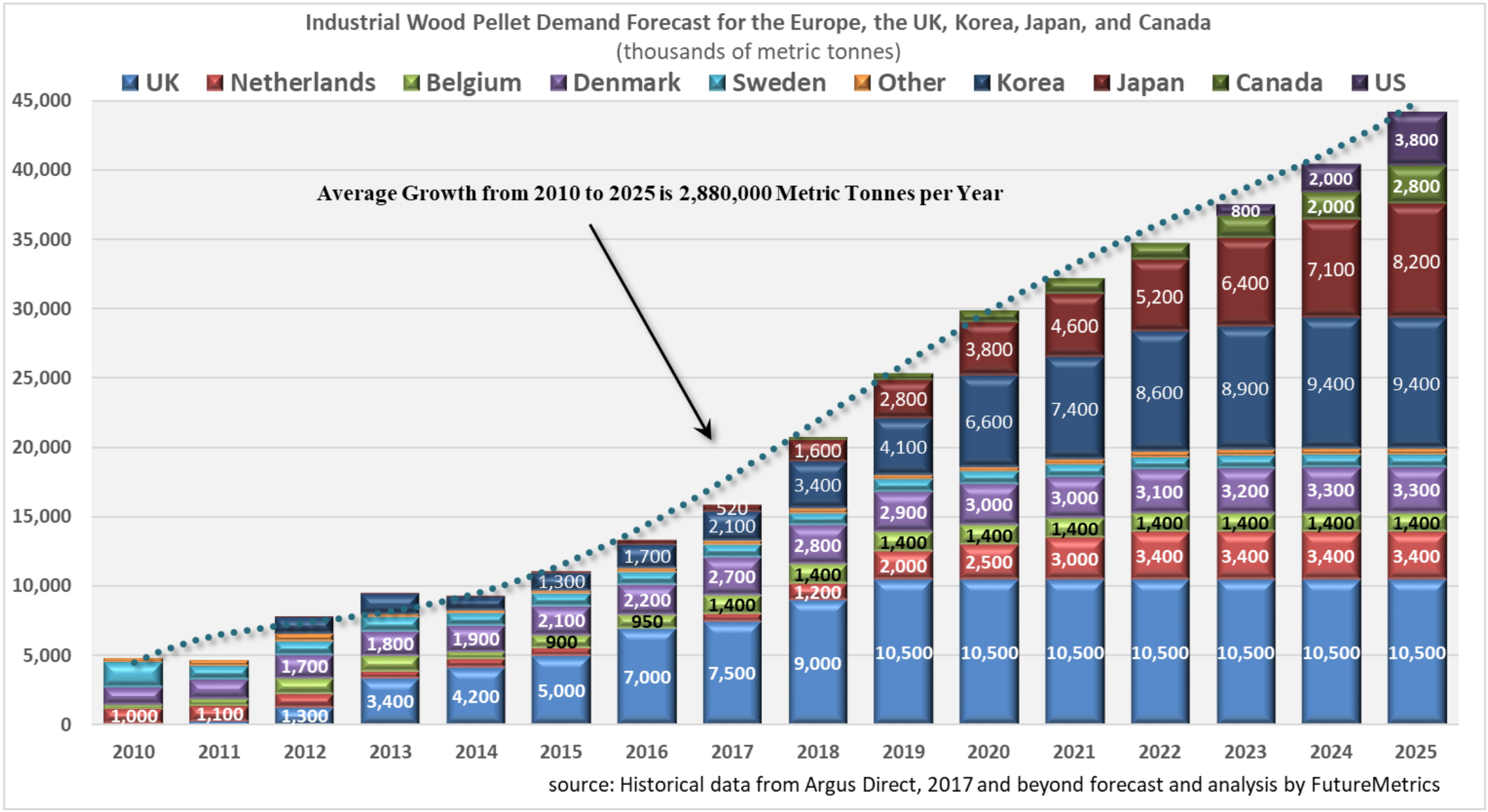
(2) **Premium heating** pellets used in pellet stoves and pellet fueled central heating systems.



Heating Pellet Markets – Driven by Economics (lowest cost heating fuel)

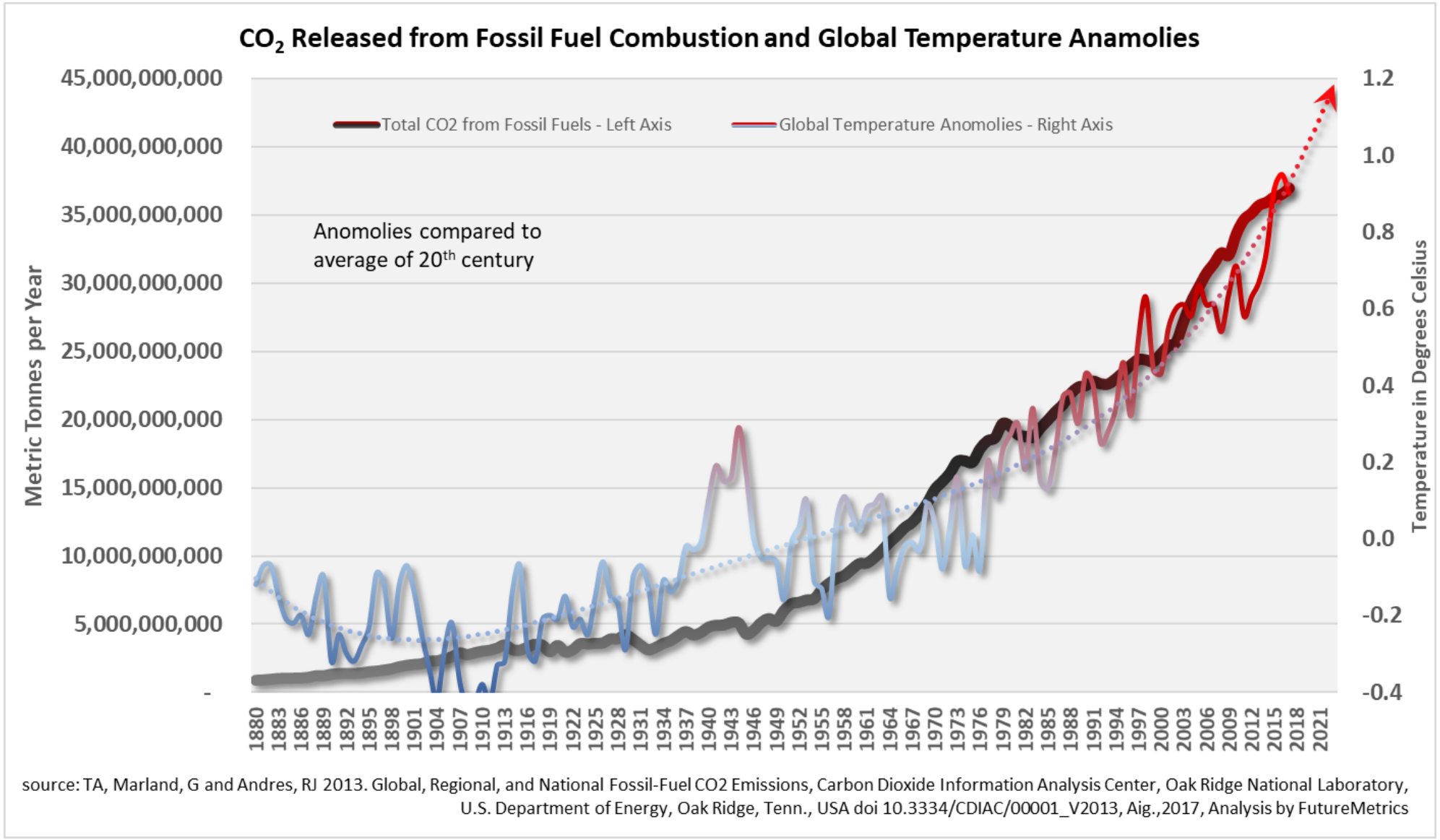


Industrial Pellet Markets – Driven by Policy



Why Pellets for Power?

Most of the countries of the world recognize the relationship shown in the chart below.



source: TA, Marland, G and Andres, RJ 2013. Global, Regional, and National Fossil-Fuel CO2 Emissions, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., USA doi 10.3334/CDIAC/00001_V2013, Aig.,2017, Analysis by FutureMetrics

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.

Managed forests provide feedstock for many industries: lumber, pulp and paper, and pellets.

Sustainably managed forests cycle CO_2 continuously.

The sustainability of the forests
(and therefore the carbon stock held by the forests)
must be certified by independent third party audits for all pellets used in power plants.

The use of upgraded densified dried sustainably produced biomass-derived solid fuel as a substitute for coal in power plants and for heating fuel in homes and businesses is a well-established option that should be included in all strategies for

a rational and pragmatic transition to a more decarbonized future.

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.

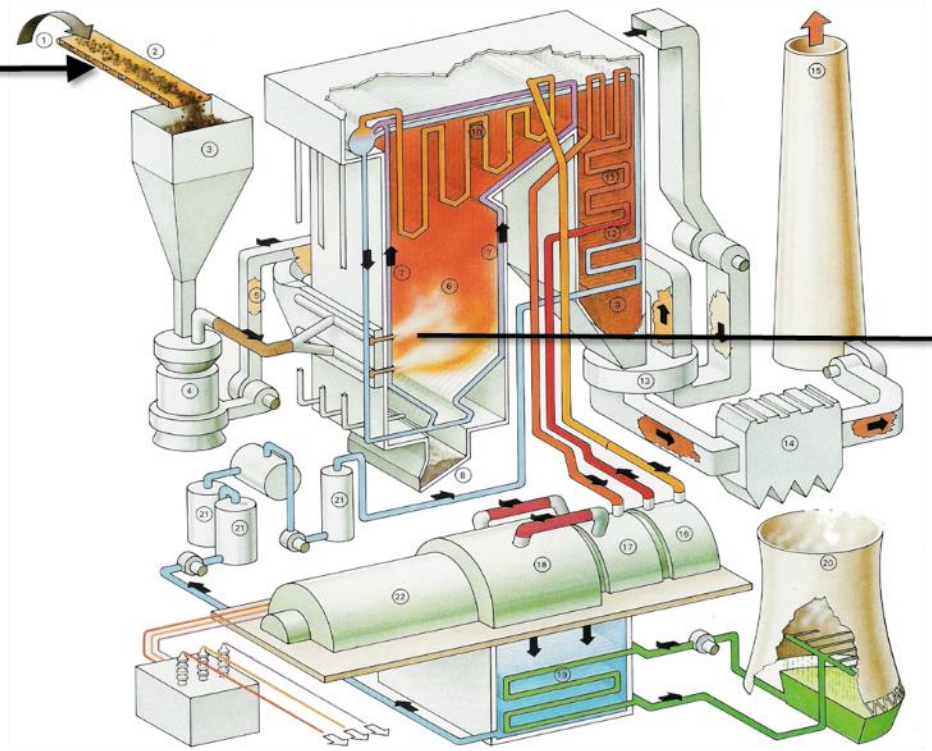
Drax Biomass 450,000 ton per year pellet fuel production plant.

Pellet Production

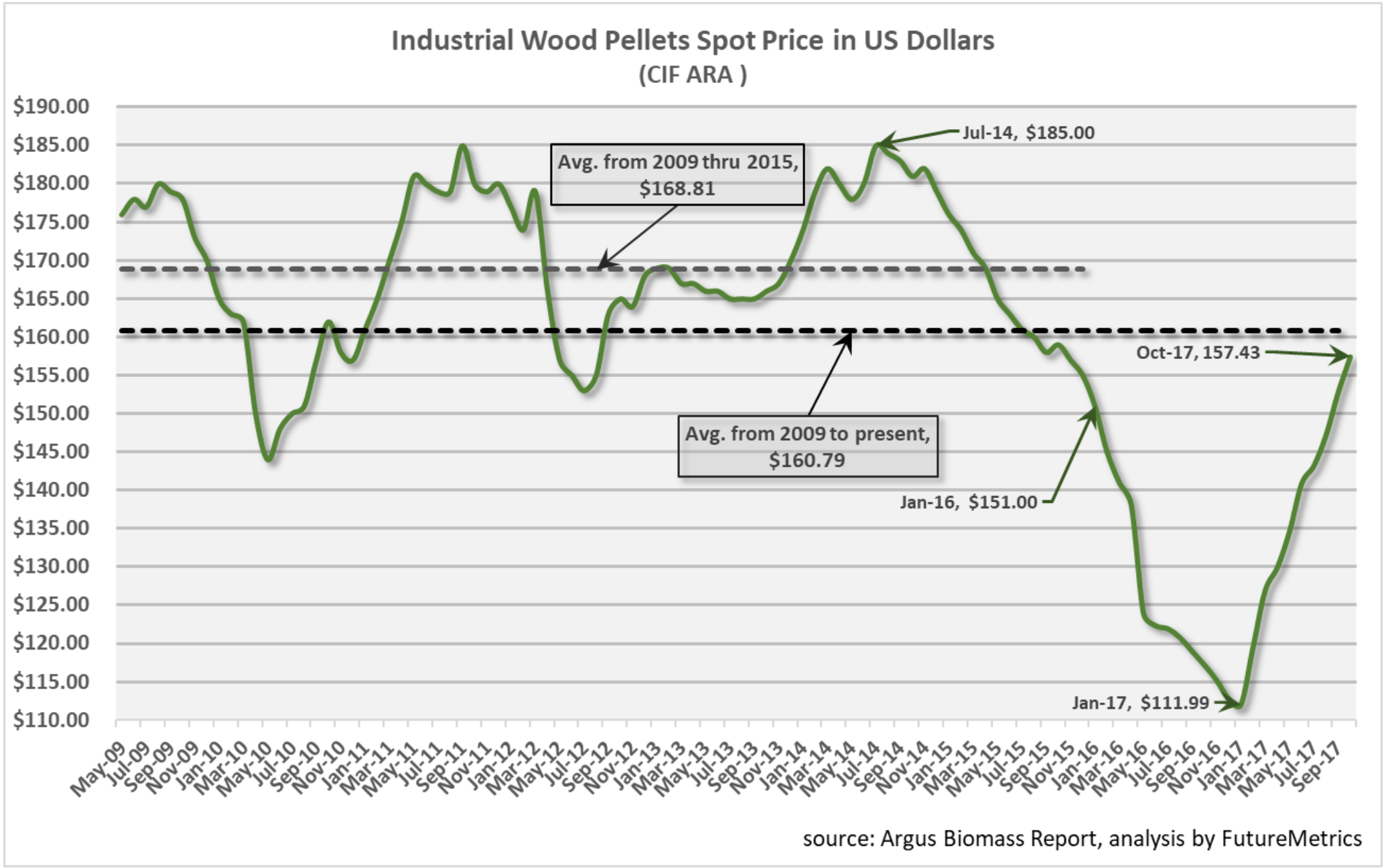
Sawdust or Chips ➔ Dry ➔ Mill ➔ Densify in Pellet Presses ➔ Cool and Condition ➔ Store ➔ Transport

With relatively low cost modifications, a typical pulverized coal fueled power station will have no loss of uptime and no de-rate.

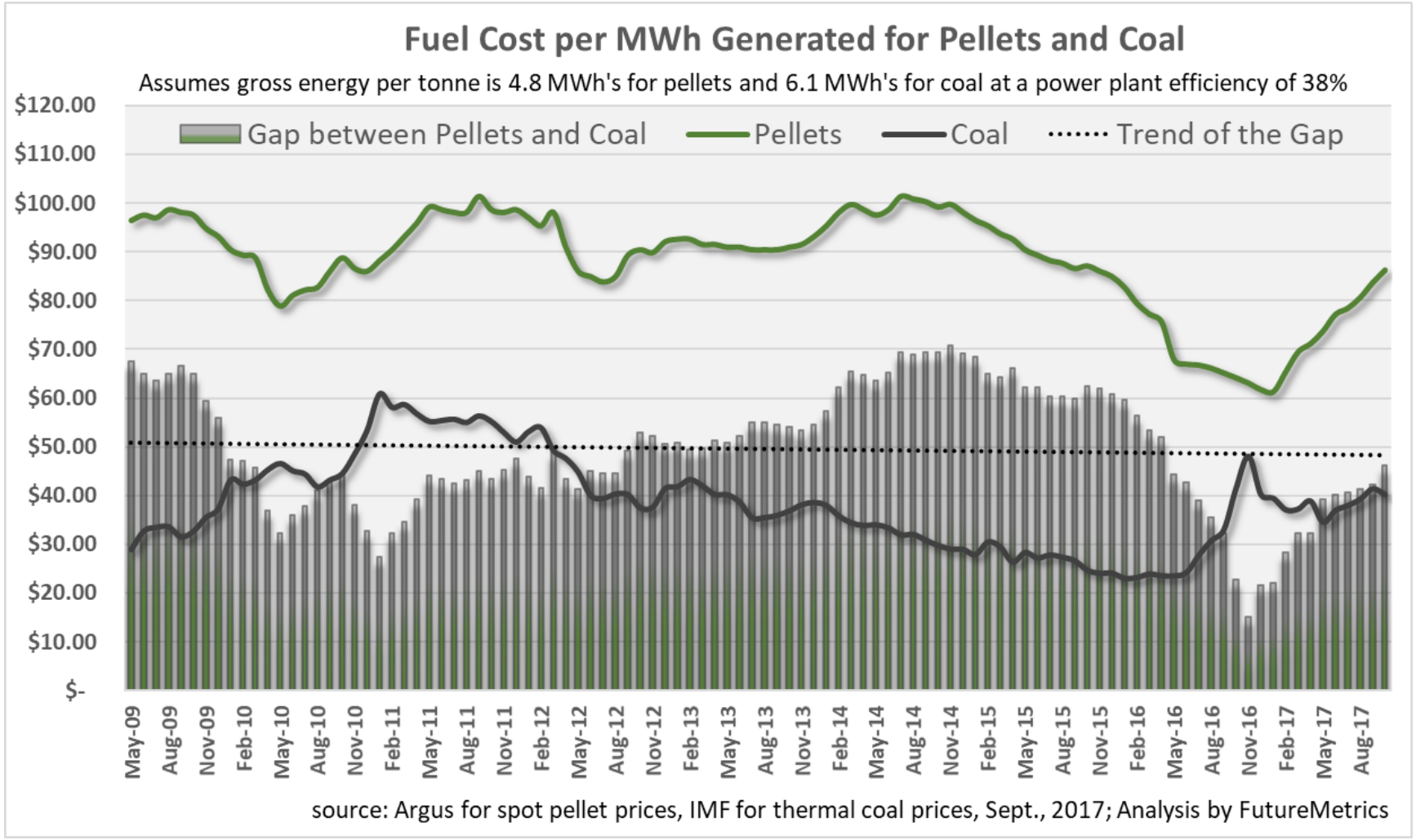
Wood pellets are used in large power boilers that rely on pulverized coal. Wood pellets pulverize and can substitute for coal. If properly modified, there is no lost of power output or reliability.



Spot Price History for Industrial Wood Pellets



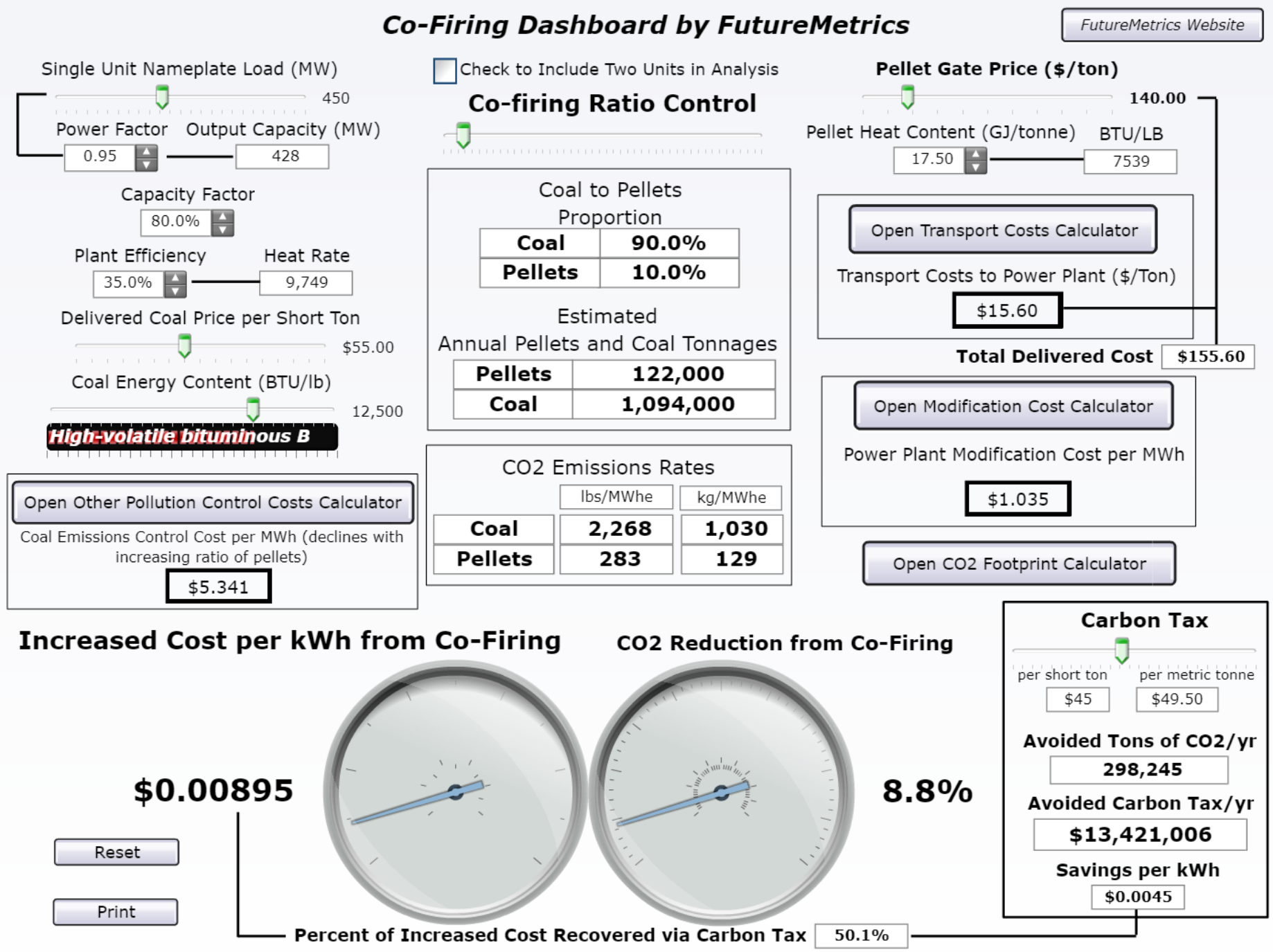
The cost of power generated from pellets in modified or converted coal power plants is higher than the cost of power generated from coal.



If the external costs of carbon emissions are considered, then policy has to close the gap.

In the countries that are co-firing or full-firing pellets, governmental policy aimed at lowering overall carbon emissions closes the gap.

Policies include subsidies to the generators and/or the ability to avoid penalties such as carbon taxes.



At a 10% co-firing ratio, the increased cost of generation is less than a penny per kWh.

Dashboard is free to use at www.FutureMetrics.com

For example, the UK has a “contract for difference” scheme.

The generator gets the current wholesale power rate and the CfD policy makes up the difference.

The net revenue per MWh is at the guaranteed rate.

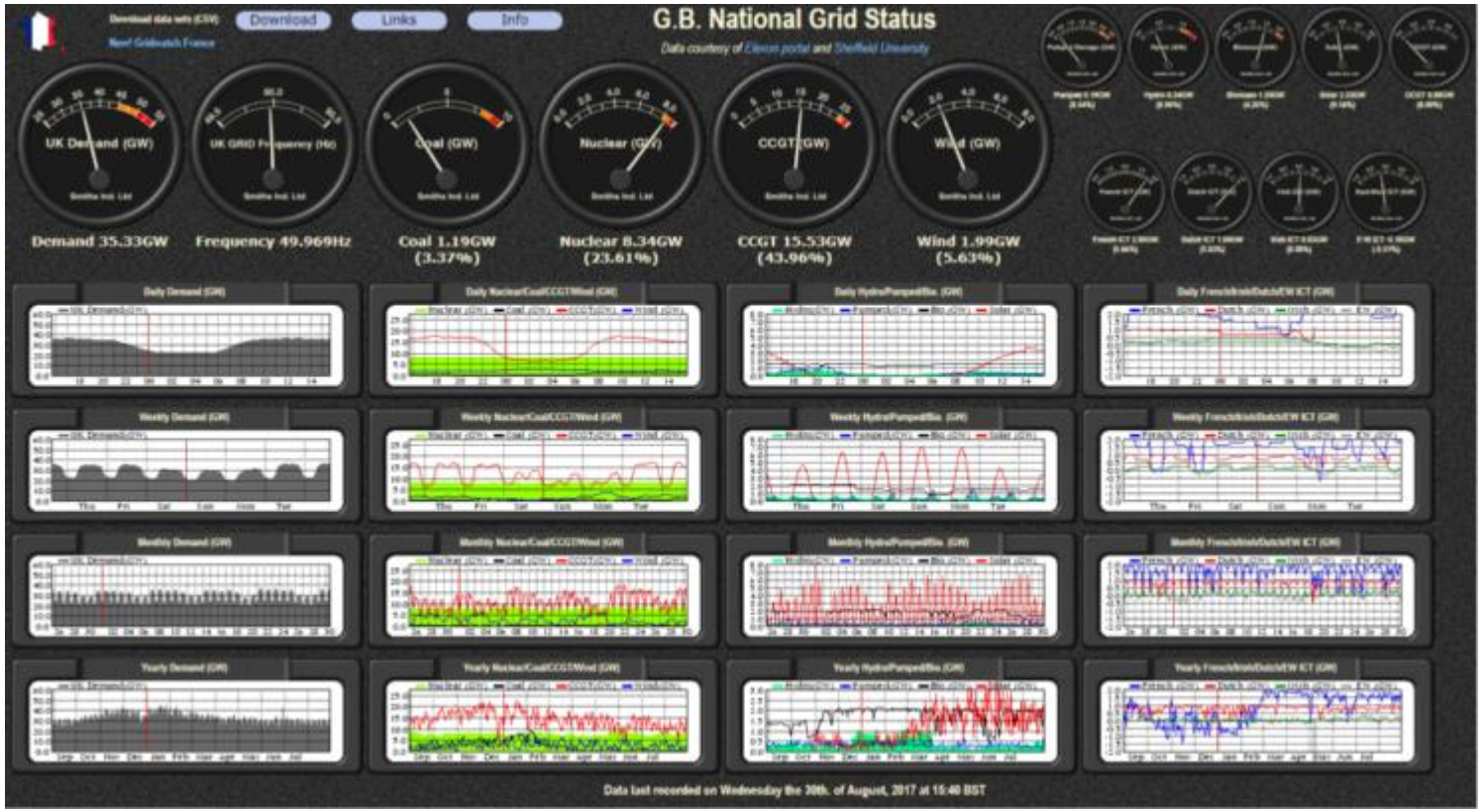
As the next few slides show, this supports a significant level of low carbon reliable <u>baseload generation from pellets</u>.

	Installed Capacity (GW)	Output (TWh)	Capacity Factor
Nuclear	9.5	16.6	81%
Pellets	2.2	3.5	79%
Hydro	1.1	0.4	19%
Wind	15.5	9.3	28%
Solar	12.4	4	16%
Natural Gas	28.4	27.7	45%
Coal	14	1.3	4%

source: Electric Insights Quarterly Q2 2017

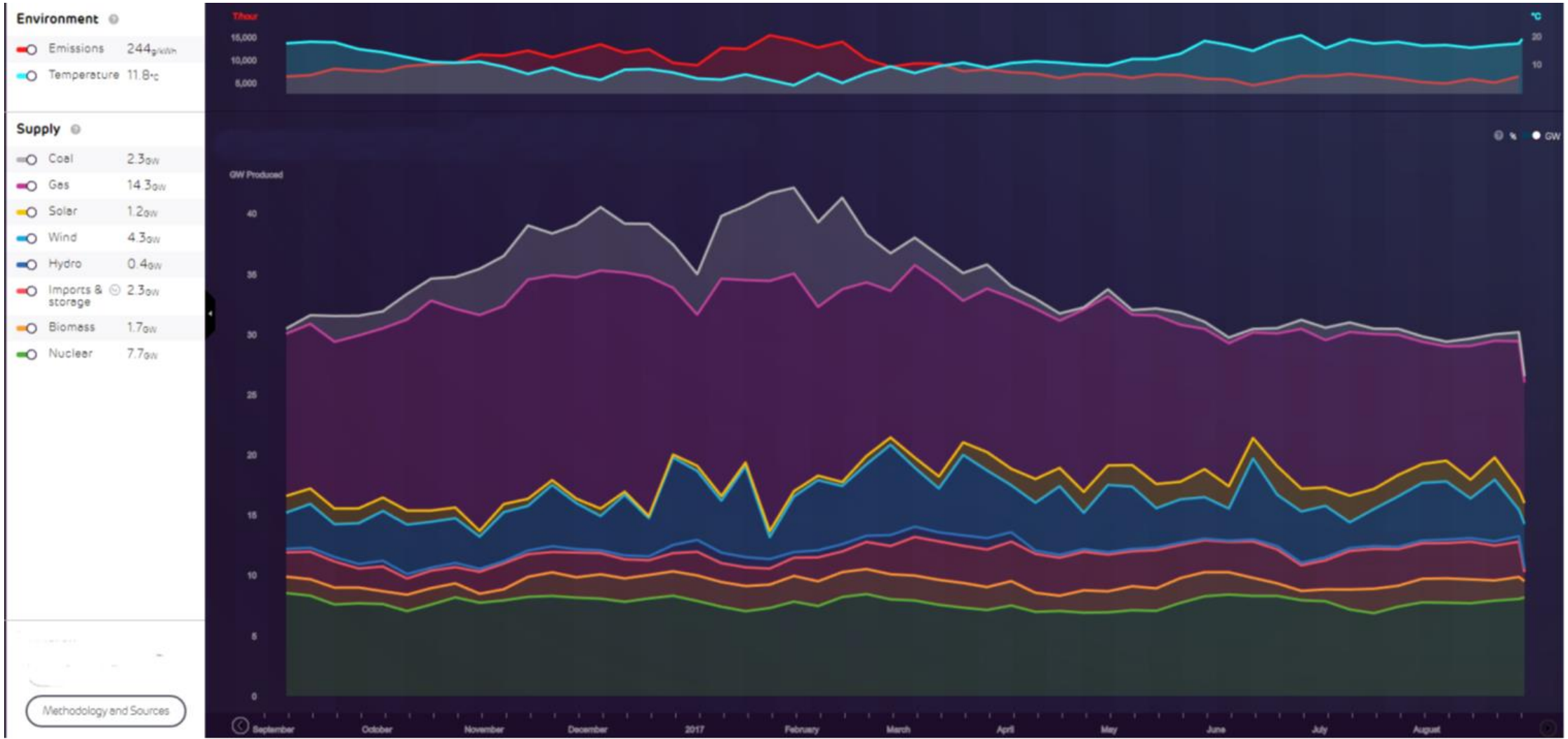
In Q2, 2017, power from pellets in the UK produced 3.5 tWh's of power at a capacity factor similar to nuclear.

Check out the current UK production in real time at http://www.gridwatch.templar.co.uk/



The power generated from pellets is shown in the orange line second from the bottom. The baseload from nuclear, pellets, and imported power form the foundation upon which the intermittency and variability of wind and solar sit.

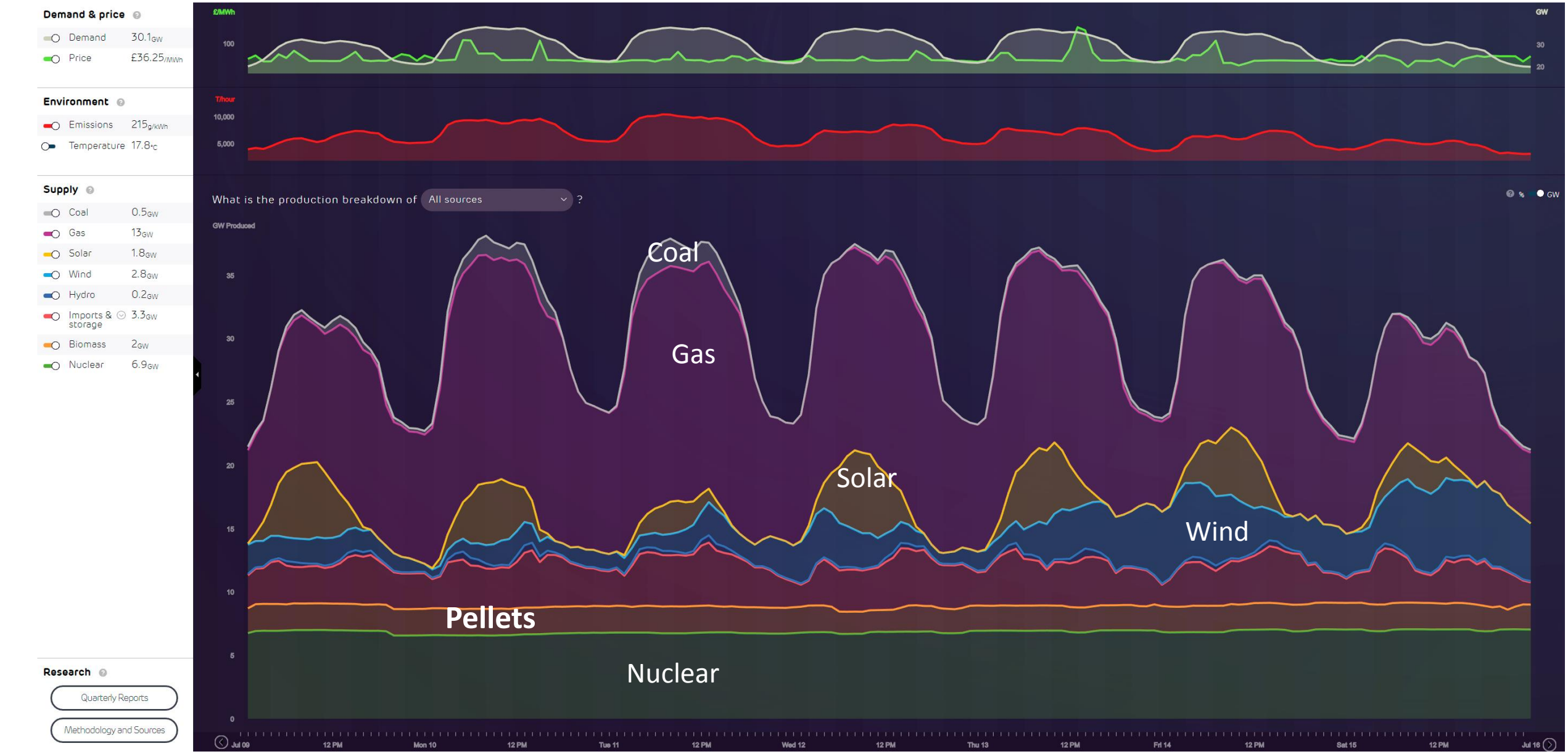
Source: Electric Insights http://electricinsights.co.uk/#/homepage?&_k=9d4yww



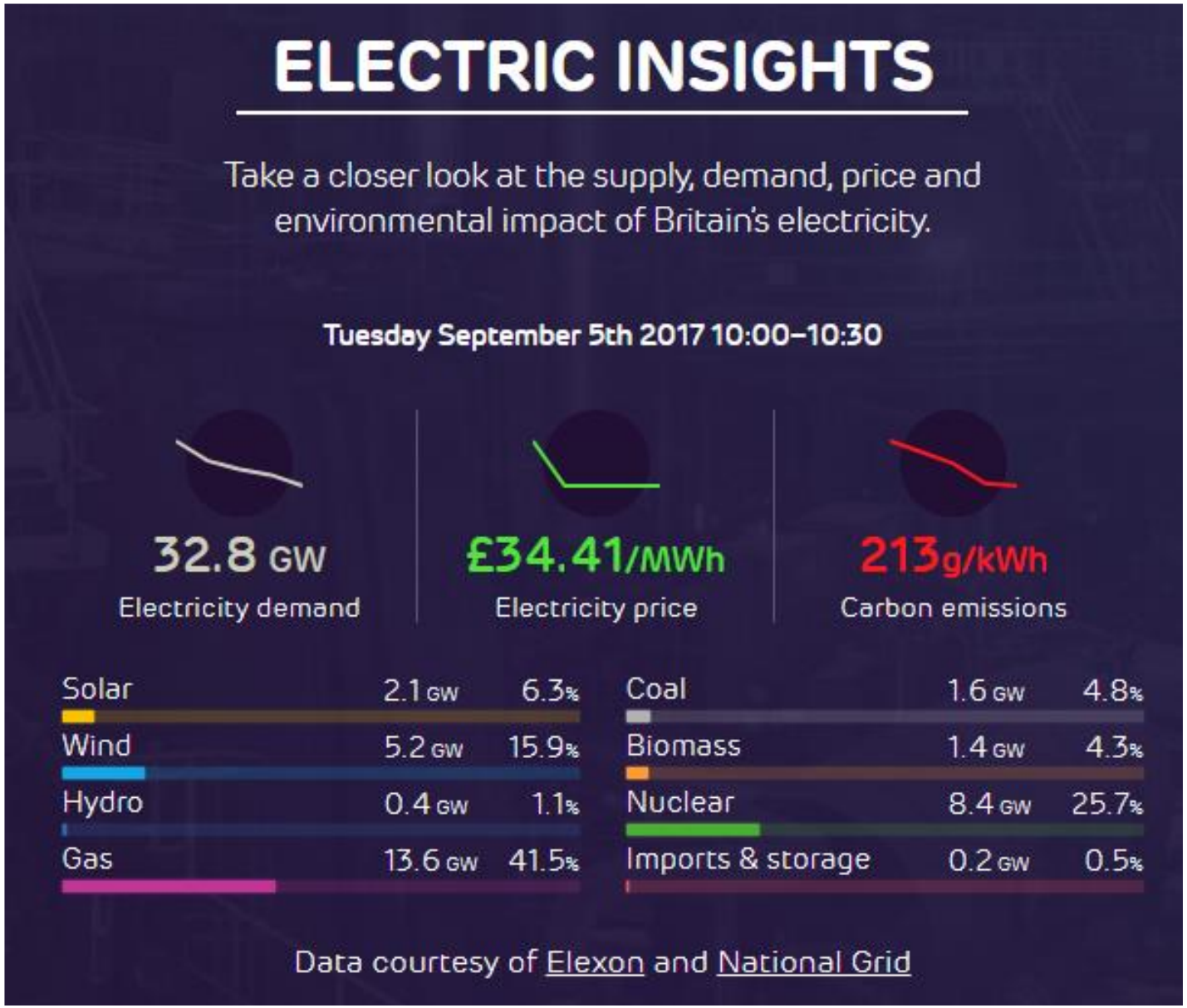
<u>One year of data.</u>

Next slide shows one week.

Over one week in the UK we can see how wind and solar fluctuate dramatically. The grid needs steady reliable low-cost baseload low-carbon power.



A snapshot of the UK grid on Sept. 5, 2017 at 10am



Wind, solar, pellets, and hydro peaked at a 51.5% share of demand on June 7th at 1 PM, with a combined output of 19.1 GW. Net carbon emissions went below 100 g/kWh.

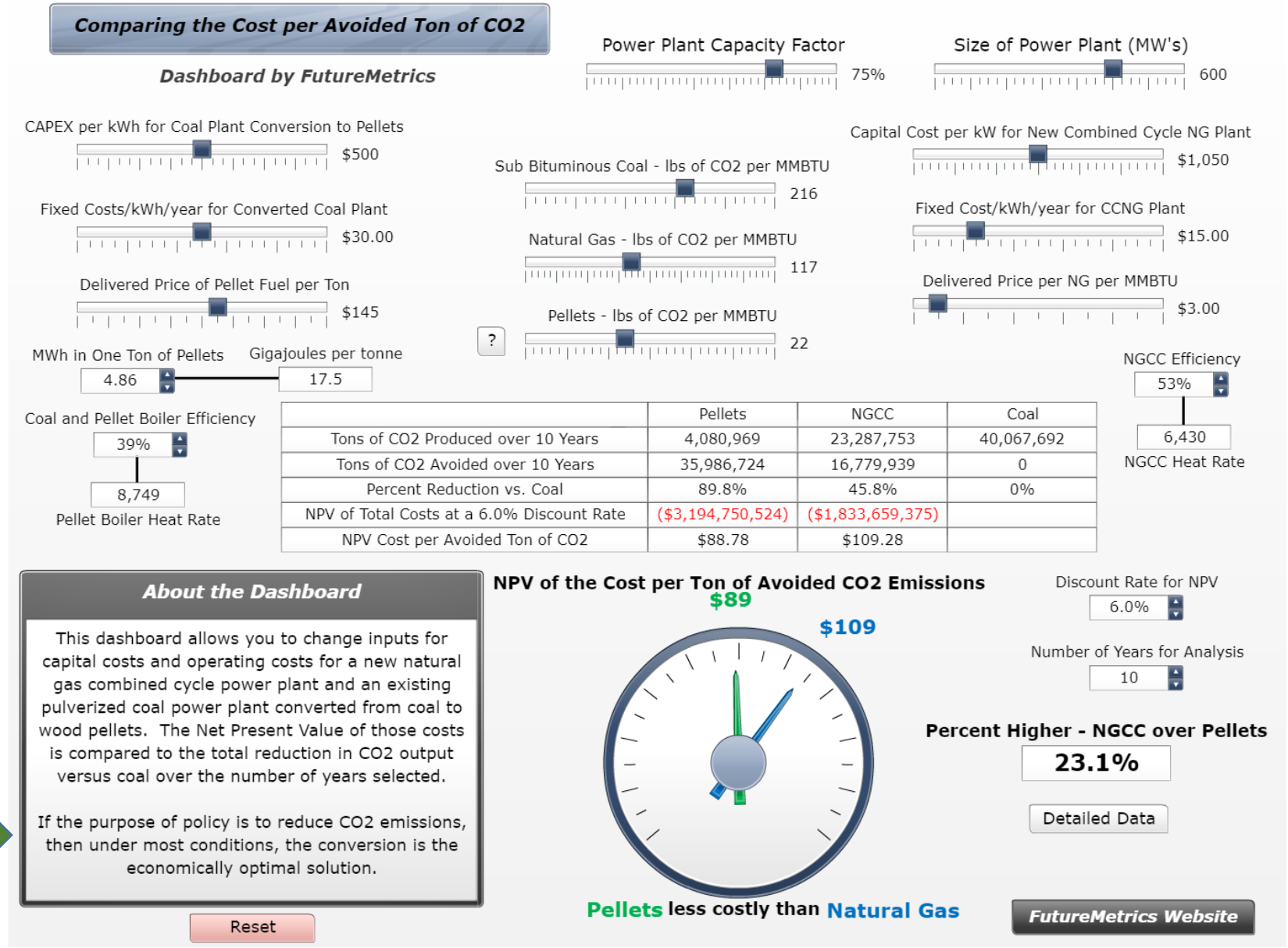
← Reliable baseload power from pellets

The substitution of wood pellets for coal either by co-firing or full conversions is a rational and pragmatic solution to moving toward a more decarbonized power sector.

Leveraging existing pulverized coal plants as part of the transition to a more decarbonized future should be part of the menu of solutions.

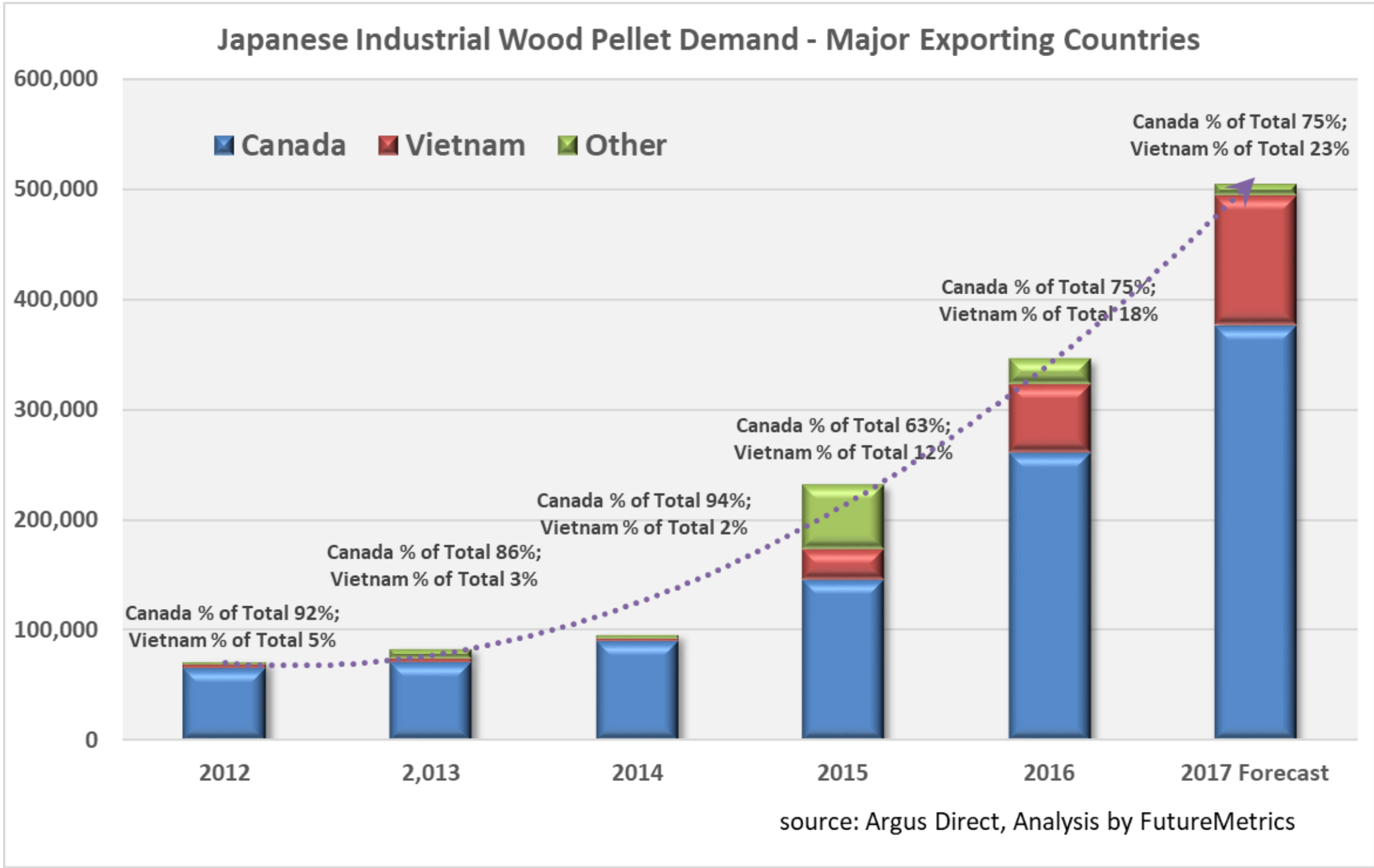
NO OTHER SOLUTION PROVIDES THE HIGHEST REDUCTION IN CO_2 EMISSIONS FOR THE LOWEST COST.

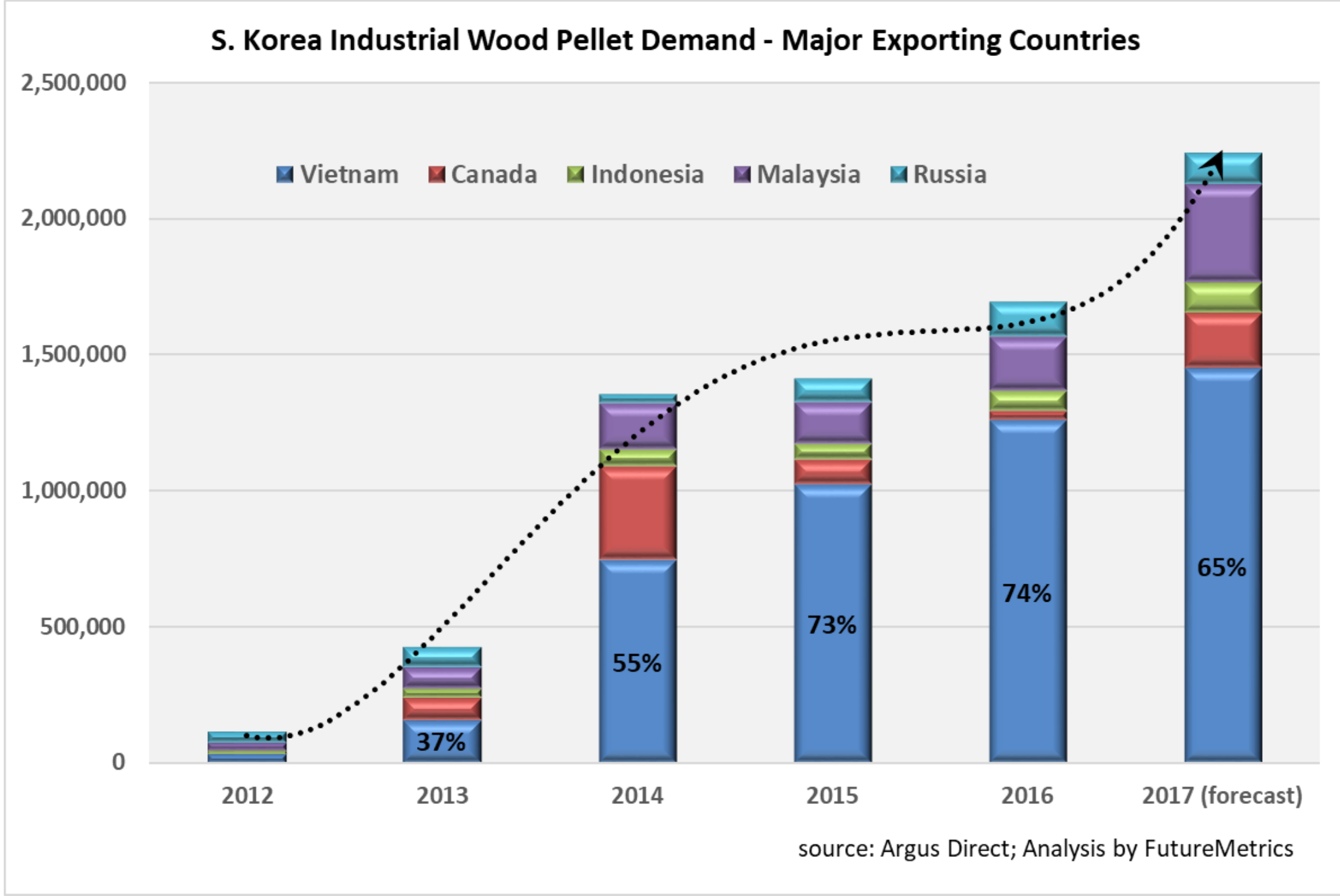
The Cost per Tonne of Avoided CO_2 Emissions is **Lower** from a Converted Coal Plant than from a New Natural Gas Combined Cycle Plant



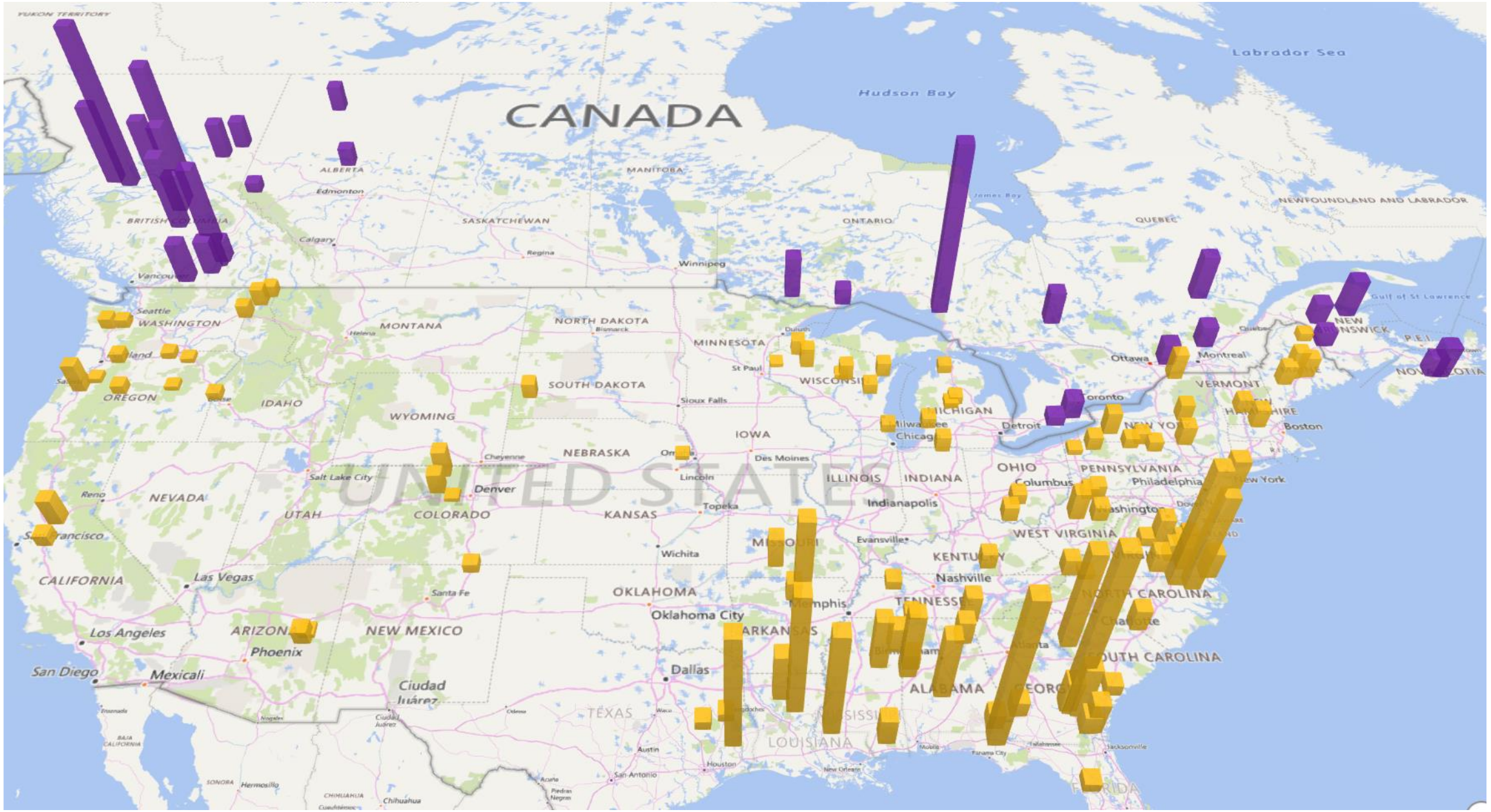
Currently, the US and Canada dominate the trade in industrial wood pellets into Europe, the UK, and Japan. Vietnam dominates the trade into S. Korea.

	Net Imports by Region (major import and export countries) - negative indicates net exports				
Region	**2013**	**2014**	**2015**	**2016**	**2017 (forecast)**
Europe and UK	4,866,320	5,655,327	6,669,874	7,407,511	8,570,000
Canada	-1,615,638	-1,607,239	-1,597,847	-2,252,201	-2,320,000
US	-2,730,078	-3,835,747	-4,368,301	-4,537,378	-5,220,000
Japan	79,052	92,539	232,060	346,518	670,000
S. Korea	484,668	1,849,639	1,469,184	1,716,346	2,530,000
Vietnam	-157,226	-742,794	-1,022,809	-1,254,955	-1,490,000
		source: Argus Direct, September 2017, Analysis and 2017 forecast by FutureMetrics			


Japanese Industrial Wood Pellet Demand - Major Exporting Countries
600,000
500,000
400,000
300,000
200,000
100,000
0
Canada
Vietnam
Other
Canada % of Total 92%;
Vietnam % of Total 5%
Canada % of Total 86%;
Vietnam % of Total 3%
Canada % of Total 94%;
Vietnam % of Total 2%
Canada % of Total 63%;
Vietnam % of Total 12%
Canada % of Total 75%;
Vietnam % of Total 18%
Canada % of Total 75%;
Vietnam % of Total 23%
2012
2,013
2014
2015
2016
2017 Forecast
source: Argus Direct, Analysis by FutureMetrics

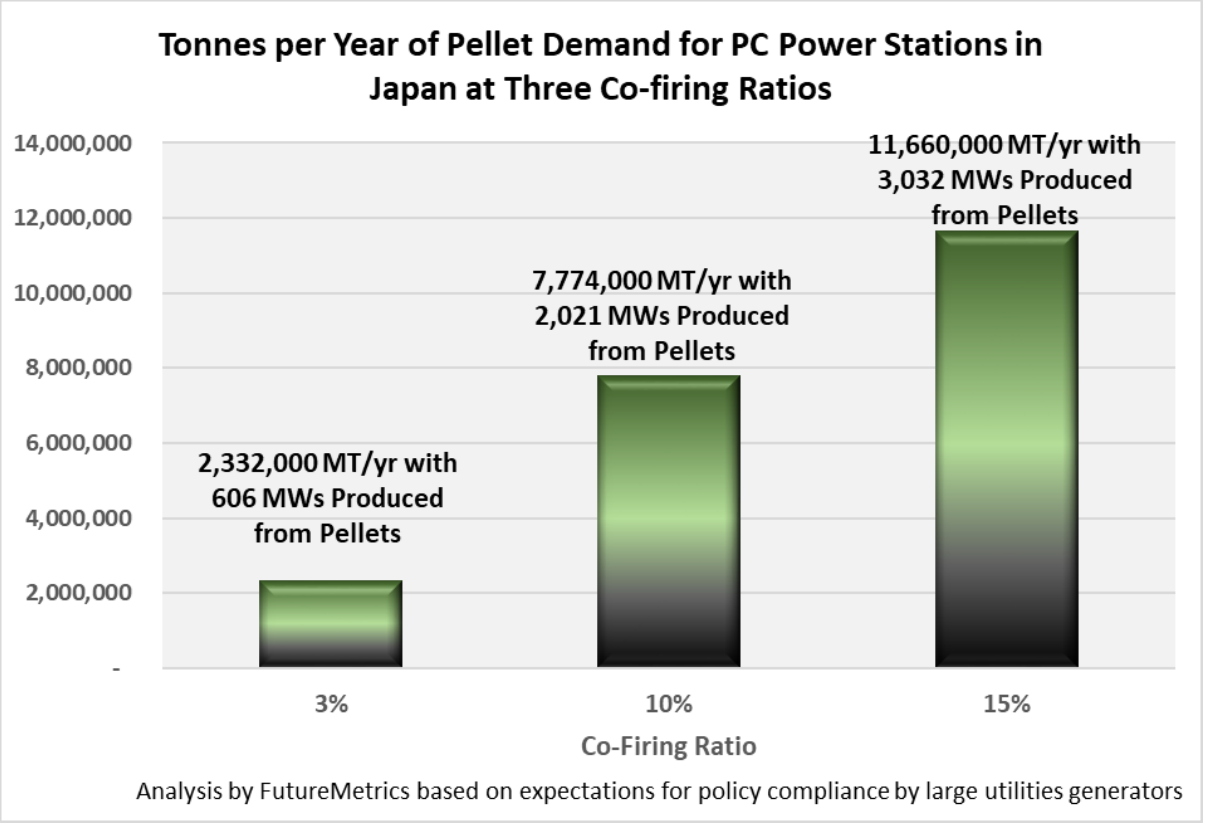

S. Korea Industrial Wood Pellet Demand - Major Exporting Countries
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Vietnam
Canada
Indonesia
Malaysia
Russia
37%
55%
73%
74%
65%
2012
2013
2014
2015
2016
2017 (forecast)
source: Argus Direct; Analysis by FutureMetrics

US and Canadian Wood Pellet Mills – height of bar represents nameplate capacity



Source: Nameplate capacity as reported by Biomass Magazine, Sept. 2017, Analysis by FutureMetrics

The Emerging Markets for Industrial Wood Pellets



Growth in Japan is expected to be strong.

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

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

Baseload under the "Best Energy Mix" ➔

Analysis of Potential Wood Pellet Demand Based on Government's Best Energy Mix Policy for 2030

Based on 1,065 Million MWh's of Demand in 2030	Energy Mix	Millions of MWh's		***Renewable Portion***	Energy Mix	Millions of MWh's	Capacity Factor	Nameplate MW's Needed	Tonnes of Wood Pellets per Year if 30% of Needed MW's are Produced from Pellets
Renewable	23%	244.95		Geothermal	1.0%	10.65	90%	1,351	
Nuclear	21%	223.65		Biomass	4.3%	45.80	85%	6,150	7,640,000
LNG	27%	287.55		Wind	1.7%	18.11	30%	6,889	
Coal	26%	276.90		Solar	7.0%	74.55	25%	34,041	
Oil	3%	31.95		Hydro	9.0%	95.85	90%	12,158	
TOTALS	100%	1,065.00			23.0%	244.95		60,589	

2030 MWh demand and energy mix from Japan Ministry of Economy, Trade, and Industry

Analysis by FutureMetrics

By 2020 all of Japan's major utilities will be required to decouple generation from transmission and distribution. Once decoupled, the FIT (¥21/kWh for 20 years) in Japan may be extended to the major utilities.

Co-firing wood pellets at in large utility pulverized coal boilers will take off quickly since little or no modification is needed to co-fire at low ratios.

Demand for industrial wood pellets could increase by many millions of tonnes per year by 2020.

Three demand scenarios:

1%, 5%, and 15% co-firing ratios.

Wood pellet demand at power stations that are or have announced that they will be co-firing wood pellets (excludes under 200 MWs)			
Capacity MW	Potential Demand at 1% co-firing	Potential Demand at 5% co-firing	Potential Demand at 15% co-firing
406	16,000	78,000	234,000
700	27,000	135,000	404,000
312	12,000	60,000	180,000
700	27,000	135,000	404,000
3,400	131,000	654,000	1,962,000
300	12,000	58,000	173,000
250	10,000	48,000	144,000
300	12,000	58,000	173,000
1,450	56,000	279,000	837,000
475	18,000	91,000	274,000
216	8,000	42,000	125,000
900	35,000	173,000	519,000
1,000	38,000	192,000	577,000
1,000	38,000	192,000	577,000
1,000	38,000	192,000	577,000
2,000	77,000	385,000	1,154,000
1,200	46,000	231,000	692,000
1,000	38,000	192,000	577,000
1,000	38,000	192,000	577,000
600	23,000	115,000	346,000
1000	38,000	192,000	577,000
1000	38,000	192,000	577,000
20,209	**776,000**	**3,886,000**	**11,660,000**

source: Argus Direct, analysis by FutureMetrics

Japanese Minimum Generation Efficiency Requirements - The Japanese regulators have set minimum generation efficiency requirements for all large coal power generation stations. The minimum requirement will be 41% and will have to be met by 2030. Currently only the ultra-supercritical pulverized coal plants meet this requirement.

The Japanese Ministry of Economy, Trade and Industry (METI) has allowed the formula for calculating efficiency to be modified to encourage the use of wood pellets as a substitute for coal to "change" the efficiency calculation. Typically, efficiency (or heat rate) is based on the energy output versus the energy input. For example, if 100 MWh's of energy are put into the boiler and 35 MWh's of electricity is generated, the efficiency is 35%.

The modification to the calculation is to allow any MWh's generated from wood pellets to be subtracted from the denominator. Thus the calculation for the example would now be:

$$efficiency = \frac{power\ out\ (MWh's)}{total\ power\ in - power\ from\ pellets\ (all\ in\ MWh's)}.$$

If the plant were producing 35MWh's and the total power is 100 MWh's but the power from pellets is 15 MWh's the "efficiency of the plant would be 35/(100-15) = 41%. In other words, power plants with efficiencies below 41% can co-fire wood pellets to achieve the minimum efficiency requirement.

Heat rate is also measures the efficiency of the system. It is the value of the energy input to a system, typically in Btu/kWh, divided by the electricity generated, in kW. The BTU content of a kWh is 3,412 BTU. The convert from efficiency to heat rate, divide 3,412 by the efficiency. For the 35% example, the heat rate is 3412/.35=9,748.

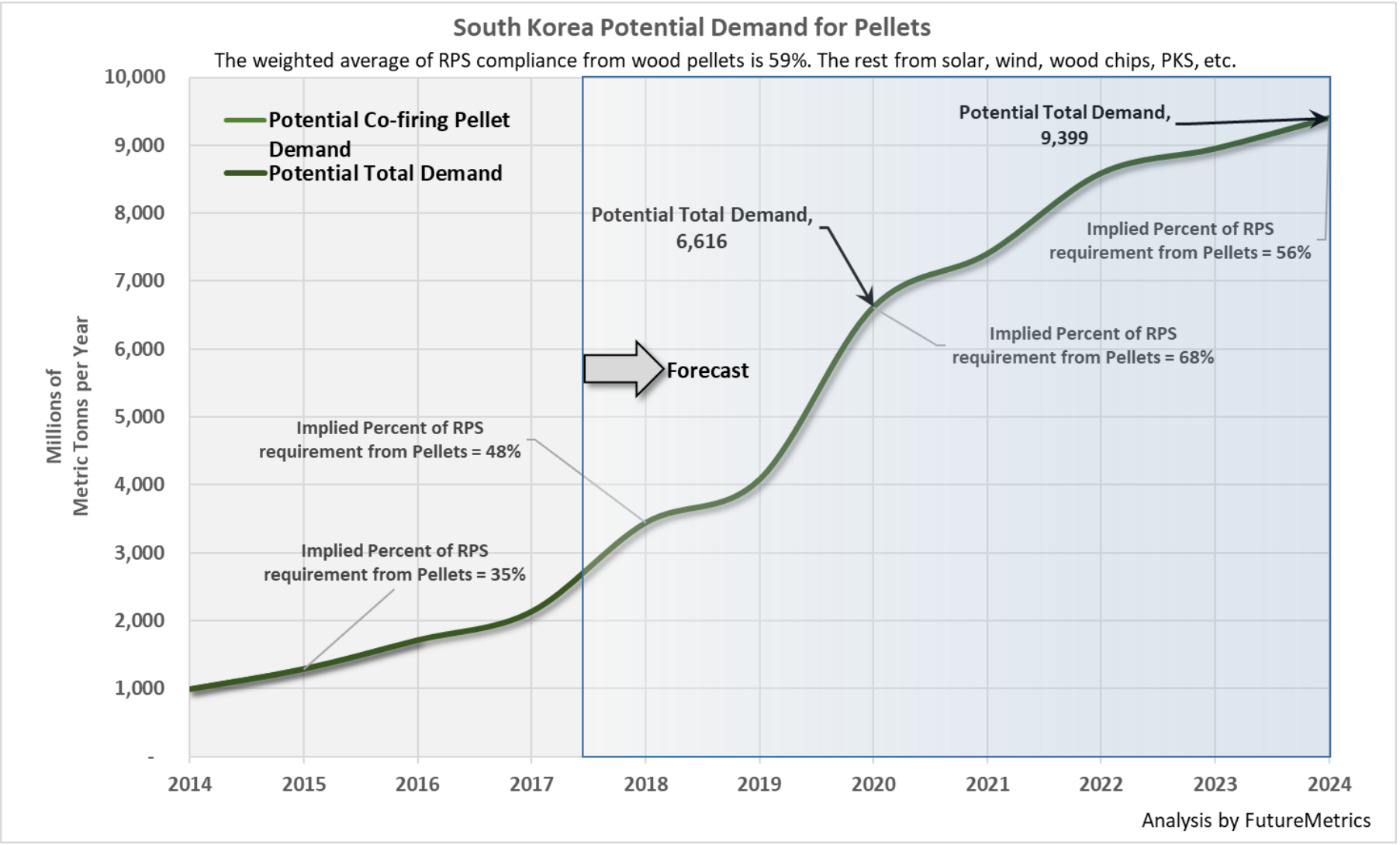
Estimated demand for pellets based only on meeting minimum efficiency requirements

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 (by weight)	Wood Pellets required (Tonnes/year)
Ultra Super-Critical	60.12%	134,600	41.5%	44,938,500	41.52%		-
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 FutureMetrics

FutureMetrics has a comprehensive report, "Japan Biomass Outlook" that will be available in early November, 2017. The report will contain information on the Japanese markets for biomass power that is not available from any other single source.

S. Korean RPS Mandates an Increasing Percentage of Power Generated from Renewable Sources. Utilities must buy RECs or pay a fine of 150% avg. REC price if they do not meet the RPS. The required proportion of power from renewables increases to 10% in 2024.



FutureMetrics has developed a model showing the power station's ability/willingness to pay based on average day ahead prices for power in S. Korea and different REC prices which define the amount of the non-compliance fines.

The S. Korean market has uncertainty because REC prices are market based. FutureMetrics has a white paper on this subject.
www.FutureMetrics.com

The substitution of wood pellets for coal either by co-firing or full conversions is a rational and pragmatic solution to moving toward a more decarbonized power sector.

Leveraging existing pulverized coal plants as part of the off-ramp to a decarbonized future should be part of the menu of solutions for every nation that has carbon reduction goals.

No other renewable strategy other than hydro can provide baseload or on-demand power.

Thank you – Bill Strauss – WilliamStrauss@FutureMetrics.com

Mountain biking in
Norway in late June, 2017