FutureMetrics LLC

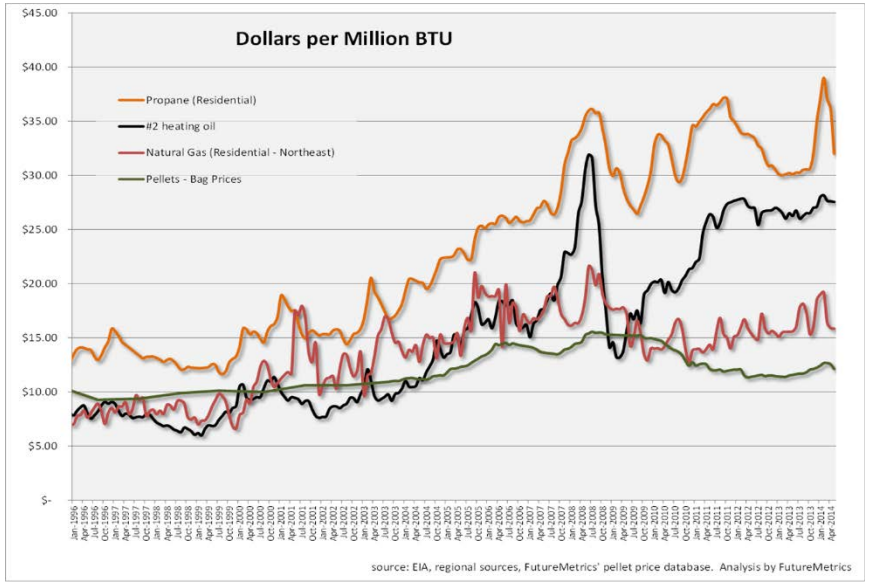
A strategy for converting coal fueled power plants to biomass that does not raise the cost of electricity and creates jobs

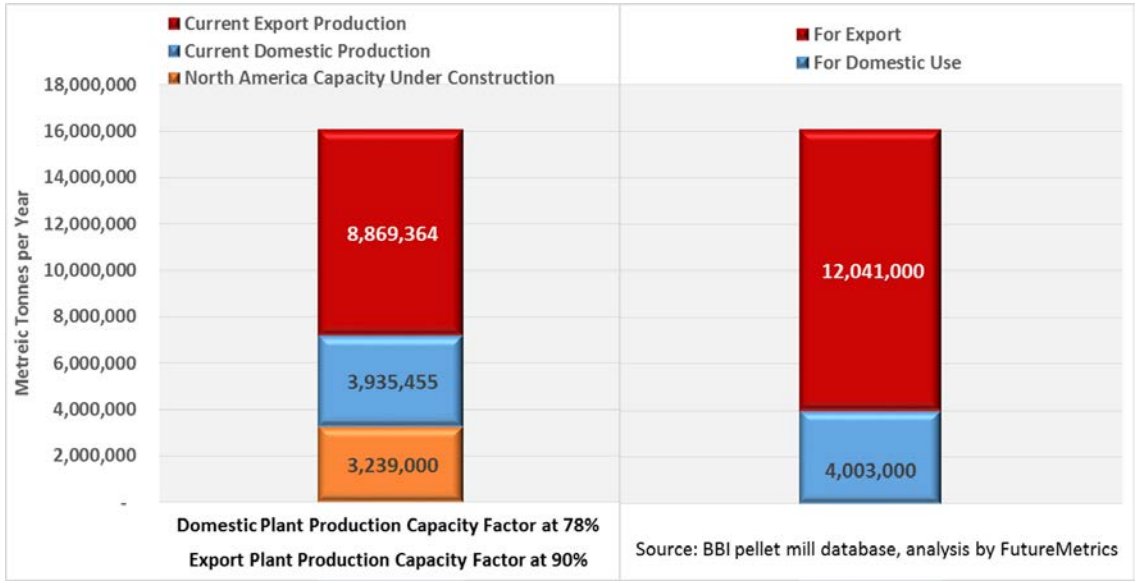
Why using Wood Pellets can be better than Wood Chips for Some Power Plant Conversions

William Strauss, PhD, President, FutureMetrics
September, 2014

FutureMetrics LLC

Pellet manufacturing project development
Expert advice / Due diligence
Investor representation
Pre-feasibility and feasibility studies
Financial modeling
Risk and decision analysis
Economic impact analysis





Dr. William Strauss, President, FutureMetrics

We can match financial needs with potential investors.

May, 2014

Deal Valued at $50.1 Million

NEW ENGLAND WOOD PELLET

Jaffrey, New Hampshire

HAS BEEN ACQUIRED BY

RENTECH

Denver, Colorado

FutureMetrics and its consulting partners initiated the acquisition process and provided early stage advice, analysis, and due diligence for Rentech

Recipient of the 2012 International Excellence in Bioenergy Award

There are basically two types of coal power stations:

<u>Stoker / Fluidized bed</u> coal boilers that burn the fuel on a grate or on a bed of ash and other materials such as sand and limestone.

<u>Pulverized</u> coal boilers that burn coal that has been milled into a very fine dust.

Conversions of coal plants to use biomass have typically been in stoker / fluid bed plants because the biomass fuel is wood chips.

Wood chips are less expensive than wood pellets. But wood chips cannot easily be used as fuel in a pulverized coal plant. Wood pellets can easily be milled to the same powder consistency as pulverized coal.

Also, chips have a much higher moisture content than pellets. This high moisture content degrades the boiler performance and results in significantly lower efficiency than is possible with pulverized dry wood pellets.

Efficiency is the amount of the original energy in the fuel that is transferred into megawatts of electricity. For chip plants efficiency is typically less than 28%. For pulverized pellet plants efficiency is the same as for coal at around 38%.

How is coal burned in a pulverized power plant boiler?

The coal is ground in to dust, pneumatically transferred to a burner in the sidewall of the boiler, and the dust blown into the burner. Combustion takes place rapidly.

Wood dust can be burned in the same burners with very minor modifications

It is technologically feasible and very cost effective to convert pulverized coal plants to pulverized pellet plants.

Large scale proof of concept is in England ➔

Drax is England's largest power plant (4000 MW).
2000 MW and 7.5 million tons per year of pellets by 2016.

Unit #2 running on 100% wood pellets and generating at full capacity – 650 MW at 38.5% efficiency – the same as when it was running on coal

The economics of power generation

There are four broad components that add up to the total cost of generation:

- The capital cost to build the plant,
- The fixed and variable operations and maintenance (O&M) costs,
- The fuel cost,
- Capacity factor.

The fuel cost is <u>not</u> the largest component of the total cost of generation.

If it were, then wind, solar, with free fuel would provide cheap electricity.

The **<u>primary component</u>** of the total cost of generation is the amortized capital costs of building the generating facility.

Capacity factor matters. Capacity factor is the ratio of actual power production to the theoretical maximum if the plant were to run at 100% of its nameplate 365 days a year.

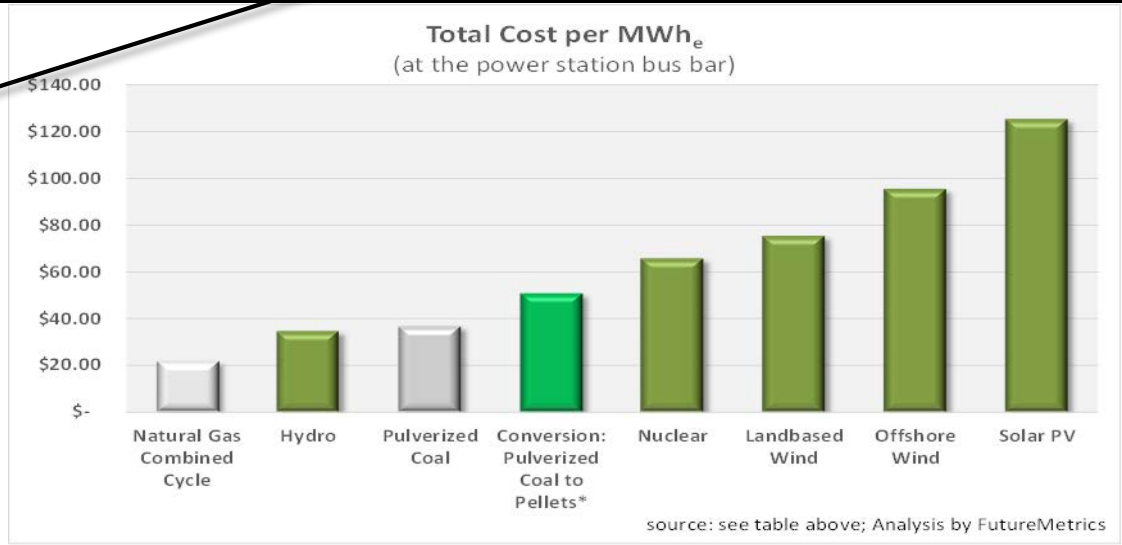
Wind and solar PV have low capacity factors so the amortized capital cost burden on each MWh produced is much higher.

Green shading for low carbon solutions			Costs amortized over	35 years		Utility Natural Gas at $5.50 per MMBTU	Coal at $2.60 per MMBTU		Pellets at $155.00 per ton	or $8.61 per MMBTU
				at	6.00%					
	Construction or Conversion Cost per kW	Size (MW)	Capacity Factor	Install Cost	Annual Capital Cost Amortization	Annual Output (MWh_e)	Fixed Capital Cost per MWh_e	Fixed and Variable O&M per MWh_e	Fuel Cost per MWh_e	**Total Cost per MWh_e (at the power station bus bar)**
Natural Gas Combined Cycle	$ 1,230	580	90.0%	$ 713,400,000	$ 49,205,951	4,572,720	$ 10.76	$ 1.70	$ 9.38	**$ 21.84**
Hydro	$ 3,500	1000	90.0%	$ 3,500,000,000	$ 241,408,506	7,884,000	$ 30.62	$ 4.10	$ -	**$ 34.72**
Pulverized Coal	$ 2,890	610	85.0%	$ 1,762,900,000	$ 121,594,016	4,542,060	$ 26.77	$ 4.20	$ 5.77	**$ 36.74**
Conversion: Pulverized Coal to Pellets*	$ 3,490	600	85.0%	$ 2,094,000,000	$ 144,431,261	4,467,600	$ 32.33	$ 5.00	$ 14.69	**$ 52.02**
Conversion: Pulverized Coal to Chips*	$ 4,090	600	75.0%	$ 2,454,000,000	$ 169,261,850	3,942,000	$ 42.94	$ 7.50	$ 12.51	**$ 62.95**
Nuclear	$ 6,100	1125	90.0%	$ 6,862,500,000	$ 473,333,107	8,869,500	$ 53.37	$ 11.80	$ 0.60	**$ 65.76**
Landbased Wind	$ 1,980	50	25.0%	$ 99,000,000	$ 6,828,412	109,500	$ 62.36	$ 13.00	$ -	**$ 75.36**
Offshore Wind	$ 3,230	50	35.0%	$ 161,500,000	$ 11,139,278	153,300	$ 72.66	$ 22.80	$ -	**$ 95.46**
Solar PV	$ 4,340	100	30.0%	$ 434,000,000	$ 29,934,655	262,800	$ 113.91	$ 11.40	$ -	**$ 125.31**

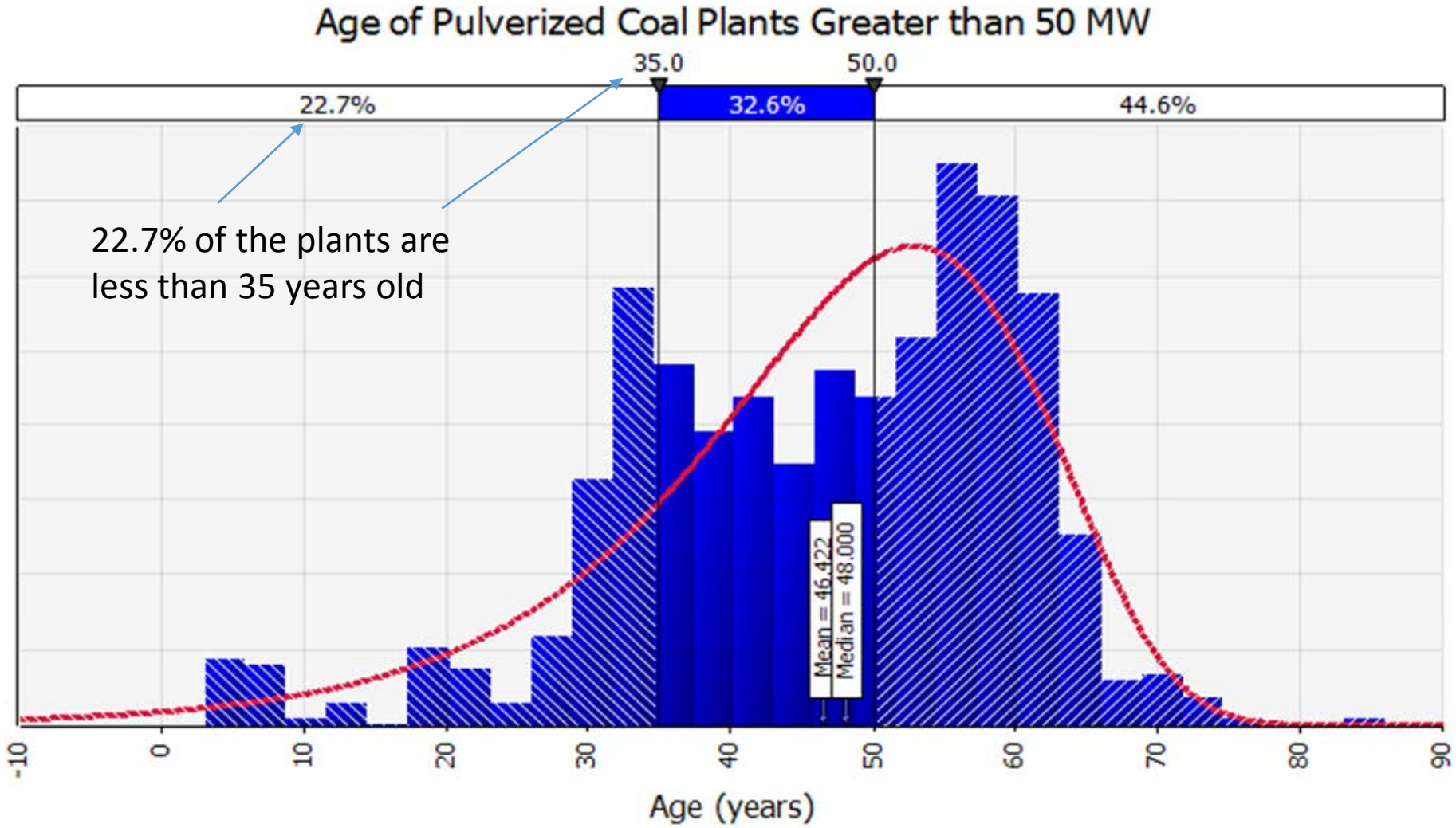
*Assumes CAPEX of coal plant plus conversion costs

Source of Data: "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the AEO", 2014, EIA, April 2014; "Cost and Performance Data for Power Generation Technologies", Prepared for NREL by Black & Veatch, February, 2012; Analysis by FutureMetrics

Free fuel but low capacity factor yields high fixed capital and O&M cost per MWh_e



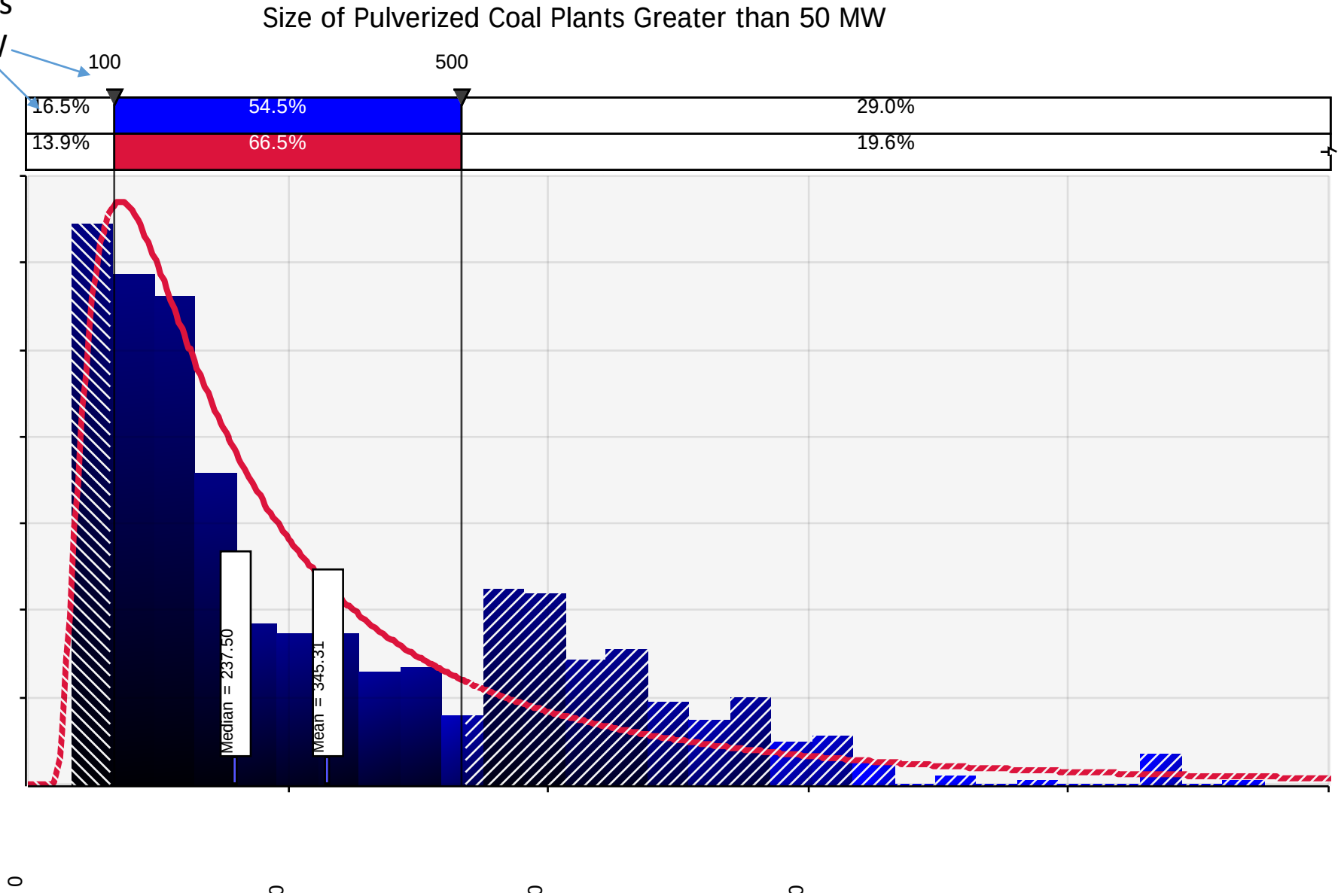
There are 428 operating pulverized coal plants in the US (greater than 50 MW). The median age is 48 years. 77.3% of the plants are older than 35 years.



Data is from the EPA Emissions & Generation Resource Integrated Database (eGRID), February, 2014.
Distribution modeling is done with Palisade @RISK software.

It would be impossible to provision all of the plants. They total 337,000 MW. Each 100 MW will consume about 380,000 tons per year of pellets at a capacity factor of 90%.

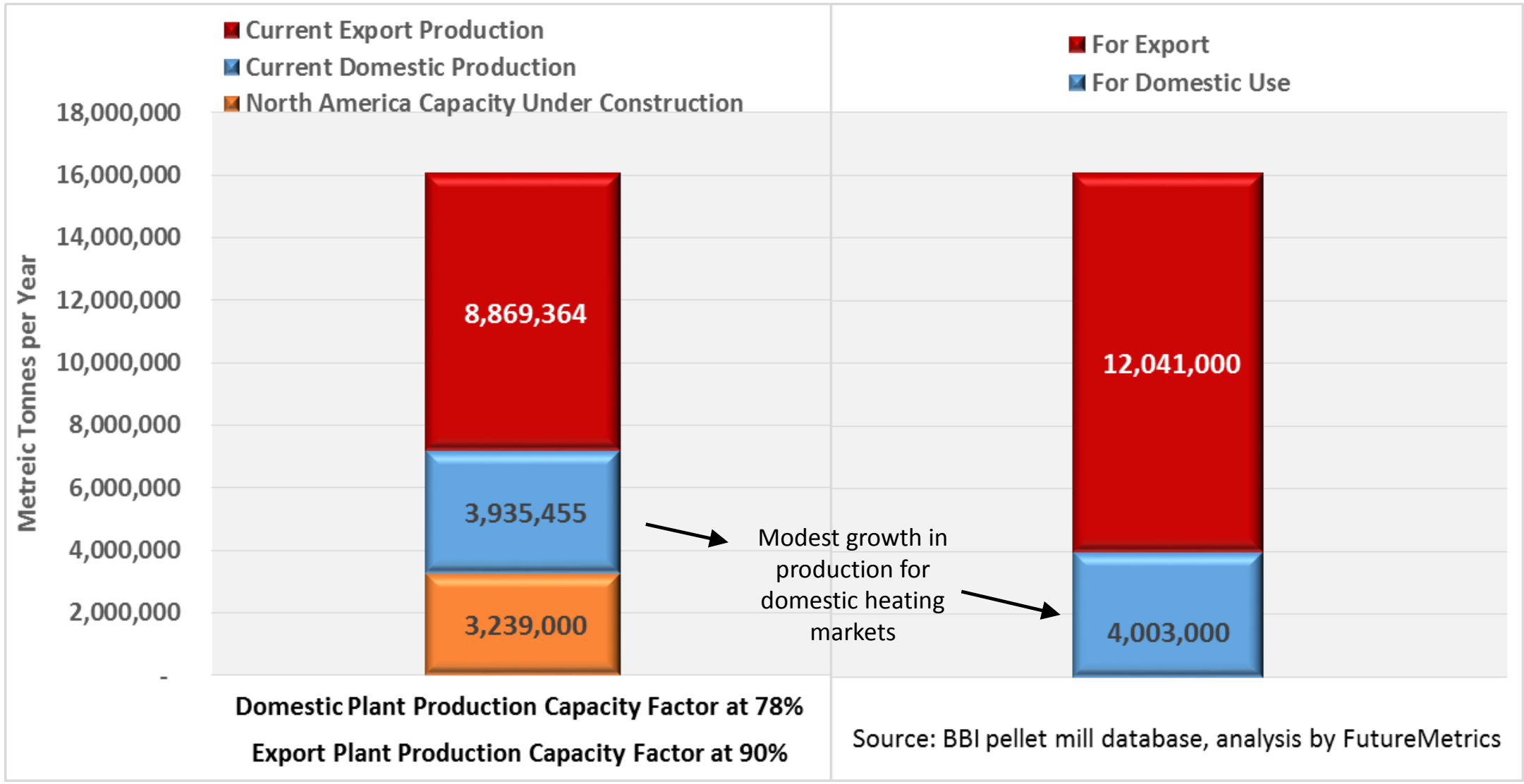
16.5% of the plants are under 100 MW



North America already has the production capacity to produce over 16 million metric tonnes per year of wood pellets.

Most of those are being exported to foreign pulverized coal plants that have converted to pulverized wood pellets.

North American Pellet Production Total is 16,044,000 metric tonnes

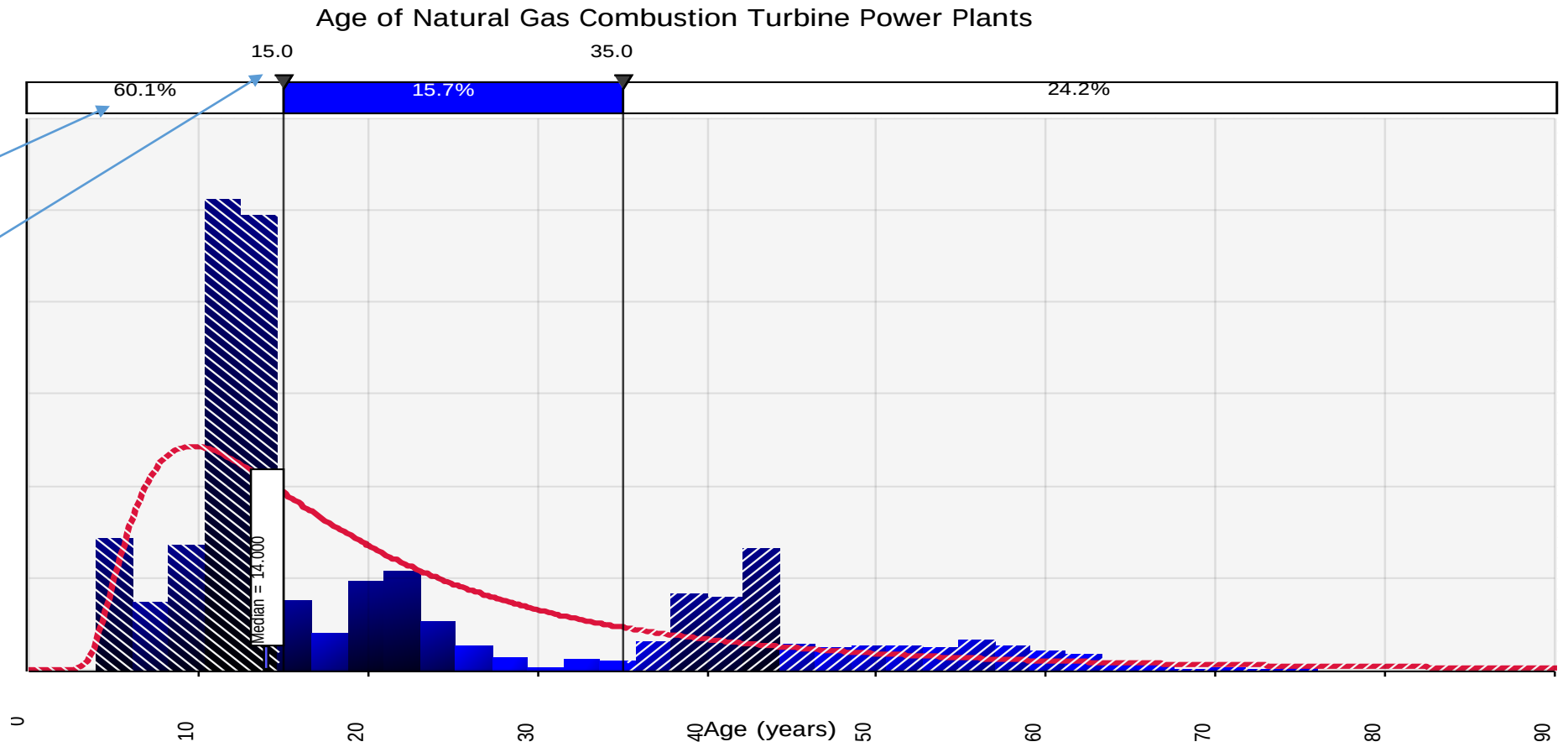


Estimate is based on nameplate at shown assumed capacity factors.
Assumption for domestic production is if US plant is smaller than 100,000 tpy it is domestic and if CA plant is less than 60,000 tpy it is domestic.

If a plant is older than 35 years it has been fully paid for. That is, the original capital cost has been fully depreciated.

Natural gas plants are relatively new. Average age = 14 years

60% of natural gas turbine plants are less than 5 years old



Data is from the EPA Emissions & Generation Resource Integrated Database (eGRID), February, 2014.
Distribution modeling is done with Palisade @RISK software.

Assume that any conversion from pulverized coal to pulverized wood pellet fuel will be plants that are older than 35 years.

In that case, the only new major capital cost for a conversion from pulverized coal to wood pellet fuel would be the fuel storage and handling systems.

Older coal plants that do not convert to wood pellet fuel will have to install new emissions control systems.

The conversion cost to pellets includes the cost of dry storage and handling, minor retrofits of the burners, and dust control systems.

The conversion cost to chips includes the cost of a stoker/fluid bed boiler retrofit, and green wood fuel handling and processing systems.

Electricity generated from pellets is the cheapest renewable other than hydro. Under these assumptions, it is cheaper than generating with wood chips.

Green shading for low carbon solutions			Costs amortized over 15 years at 6.00%			Utility Natural Gas at $5.50 per MMBTU	Coal at $2.60 per MMBTU		Pellets at $155.00 per ton	Pellets at or $8.61 per MMBTU
	Construction, Conversions and New Pollution Control Cost for Coal Plant per kW	Size (MW)	Capacity Factor	Install Cost	Annual Capital Cost Amortization	Annual Output (MWh_e)	Fixed Capital Cost per MWh_e	Fixed and Variable O&M per MWh_e	Fuel Cost per MWh_e	**Total Cost per MWh_e (at the power station bus bar)**
Hydro	$ -	1000	90.0%	$ -	$ -	7,884,000	$ -	$ 4.10	$ -	**$ 4.10**
Pulverized Coal (older than 35 years)**	$ 380	610	85.0%	$ 231,800,000	$ 23,866,769	4,542,060	$ 5.25	$ 5.60	$ 5.77	**$ 16.62**
Natural Gas Combined Cycle	$ 1,230	580	90.0%	$ 713,400,000	$ 73,453,636	4,572,720	$ 16.06	$ 1.70	$ 9.38	**$ 27.15**
Conversion: Pulverized Coal to Pellets*	$ 650	600	90.0%	$ 390,000,000	$ 40,155,478	4,730,400	$ 8.49	$ 5.50	$ 22.28	**$ 36.27**
Conversion: Stoker/Fluid Bed to Chips*	$ 1,200	600	75.0%	$ 720,000,000	$ 74,133,190	3,942,000	$ 18.81	$ 8.00	$ 12.40	**$ 39.21**
Nuclear	$ 6,100	1125	90.0%	$ 6,862,500,000	$ 706,581,968	8,869,500	$ 79.66	$ 11.80	$ 0.60	**$ 92.06**
Landbased Wind	$ 1,980	50	25.0%	$ 99,000,000	$ 10,193,314	109,500	$ 93.09	$ 13.00	$ -	**$ 106.09**
Offshore Wind	$ 3,230	50	35.0%	$ 161,500,000	$ 16,628,486	153,300	$ 108.47	$ 22.80	$ -	**$ 131.27**
Solar PV	$ 4,340	100	30.0%	$ 434,000,000	$ 44,685,840	262,800	$ 170.04	$ 11.40	$ -	**$ 181.44**

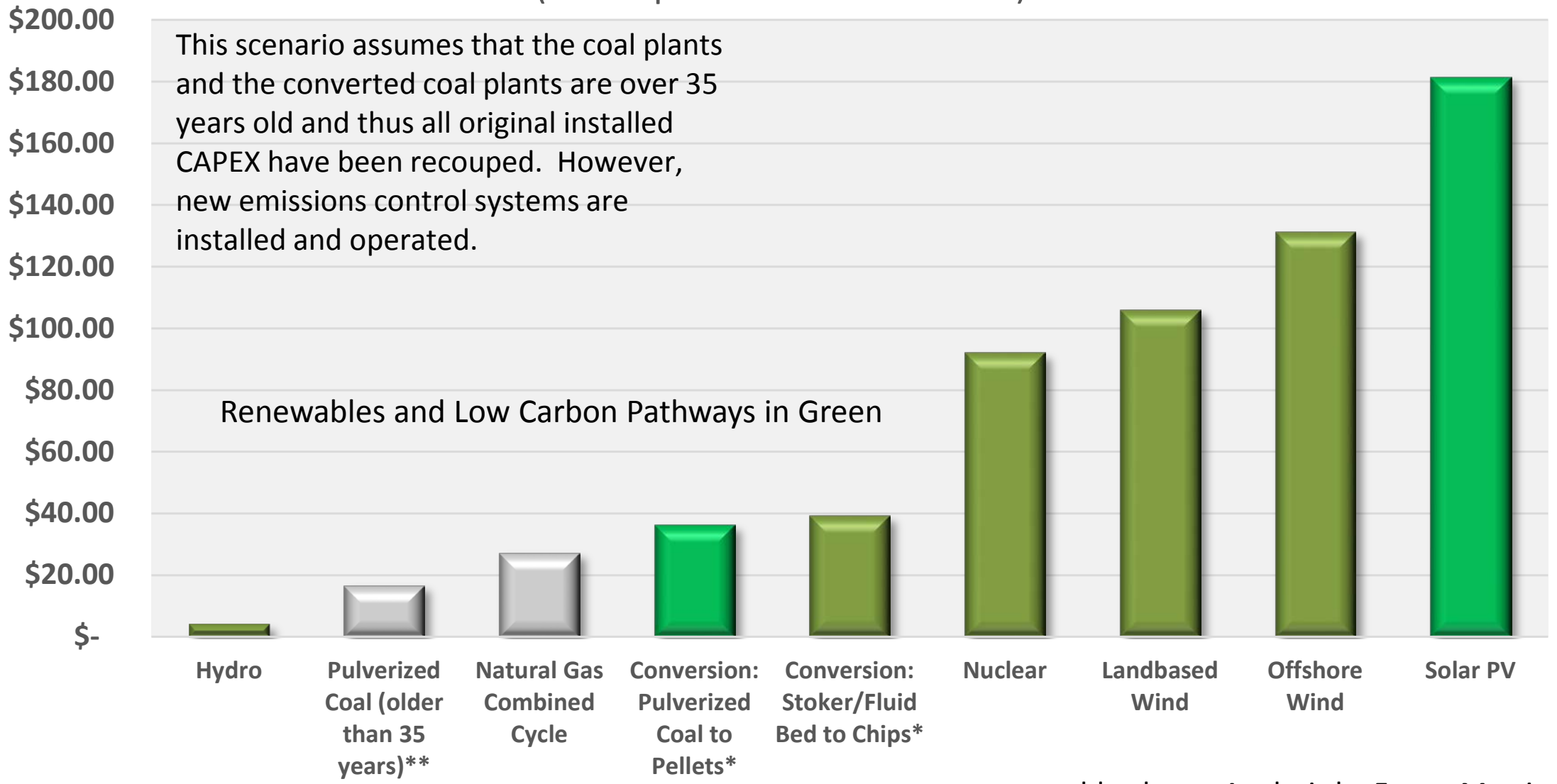
*Assumes CAPEX is only for the conversion since the plants are over 35 years old and all installed CAPEX costs have been recouped.

** New CAPEX is for emissions controls for SO2, Nox, and mercury. Higher O&M cost are for operating the flue gas contol systems. Values from a number of plant case studies.

Source of Data: "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the AEO", 2014, EIA, April 2014; "Cost and Performance Data for Power Generation Technologies", Prepared for NREL by Black & Veatch, February, 2012; Analysis by FutureMetrics

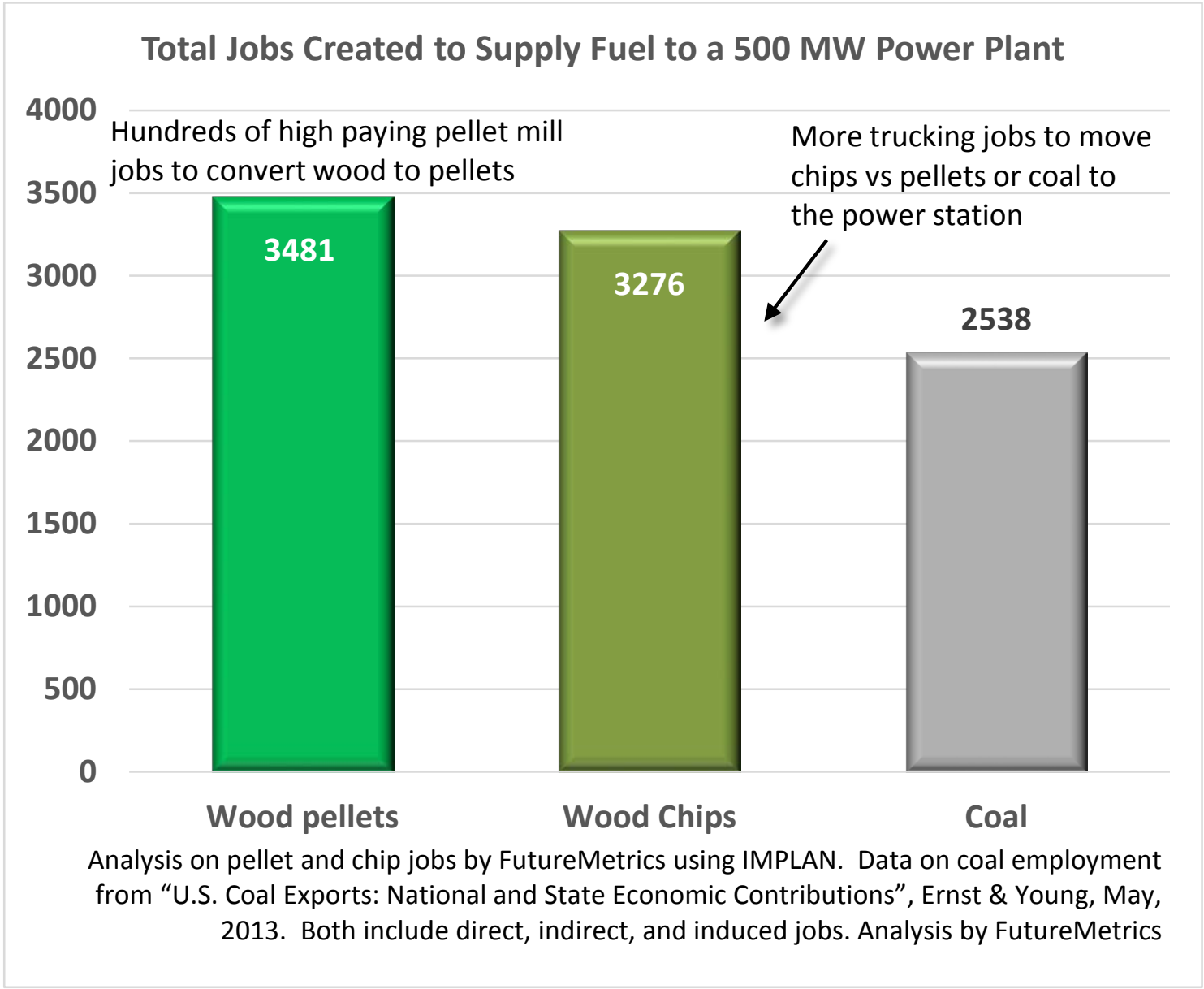
Total Cost per MWh_e

(at the power station bus bar)



source: see table above; Analysis by FutureMetrics

As an added bonus, low carbon baseload biomass fueled power plants create needed jobs while generating low cost power.



Analysis on pellet and chip jobs by FutureMetrics using IMPLAN. Data on coal employment from "U.S. Coal Exports: National and State Economic Contributions", Ernst & Young, May, 2013. Both include direct, indirect, and induced jobs. Analysis by FutureMetrics

This is a strategy that does not need R&D, does not need massive subsidies, and does not need any significant new infrastructure.

The difference in cost between a natural gas power plant and a converted coal plant using low carbon wood pellet fuel is about $9.12/MWh or not even one penny per kilowatt-hour ($0.009/kWh).

That includes the cost of dry storage and handling for the pellet scenario!

www.FutureMetrics.com

FutureMetrics

Globally Respected Consultants in the Wood Pellet Sector