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# A Cost Effective, Job Creating, and Ready to Deploy Strategy for Baseload Dispatchable Low Carbon Power Generation

By William Strauss, PhD, June, 2014

**This white paper shows that converting old pulverized coal power plants to use wood pellet fuel rather than coal provides a low carbon ready to go solution for meeting carbon mitigation goals. The strategy does not cost jobs. In fact the strategy creates new jobs.**

In an earlier paper[1] we described why the conversion of pulverized coal power plants from coal to pellets should be a part of the strategy for energy independence, for lowering the net carbon output of our power sector, and for long-term security for fuel.

> "The transition from fossil fuels to low carbon emitting renewable energy for power production is necessary if we are going to mitigate the carbon effects on climate change. But there are serious constraints to the typically envisioned pathway of using wind and solar power. For every megawatt of wind and solar generating capacity there has to be a megawatt of thermally generated or hydro capacity otherwise if the wind is not blowing and the sun is not shining, some of the lights will go out.
>
> The infrastructure for generating low carbon electricity from sustainable wood pellet fuel is in place. With relatively minor modifications, a power plant that uses pulverized coal in its boilers can use pulverized wood pellets."

We also noted in that same paper that, "Wood pellet fuel, today, is more costly than coal." **But by how much does that higher fuel cost increase the total cost of generation and is this a job destroying pathway to lowering carbon emissions?**

This white paper takes a look at the cost of generation for 8 power generation pathways.

The data used in the analysis[2] shows that converting an older pulverized coal power plant to wood pellet fuel results in a cost per megawatt-hour (MWh) that is surprisingly low and very competitive relative to other power generation methods. This analysis also shows that more jobs are needed to supply pellet fuel than are need to supply coal for the equivalent power output.

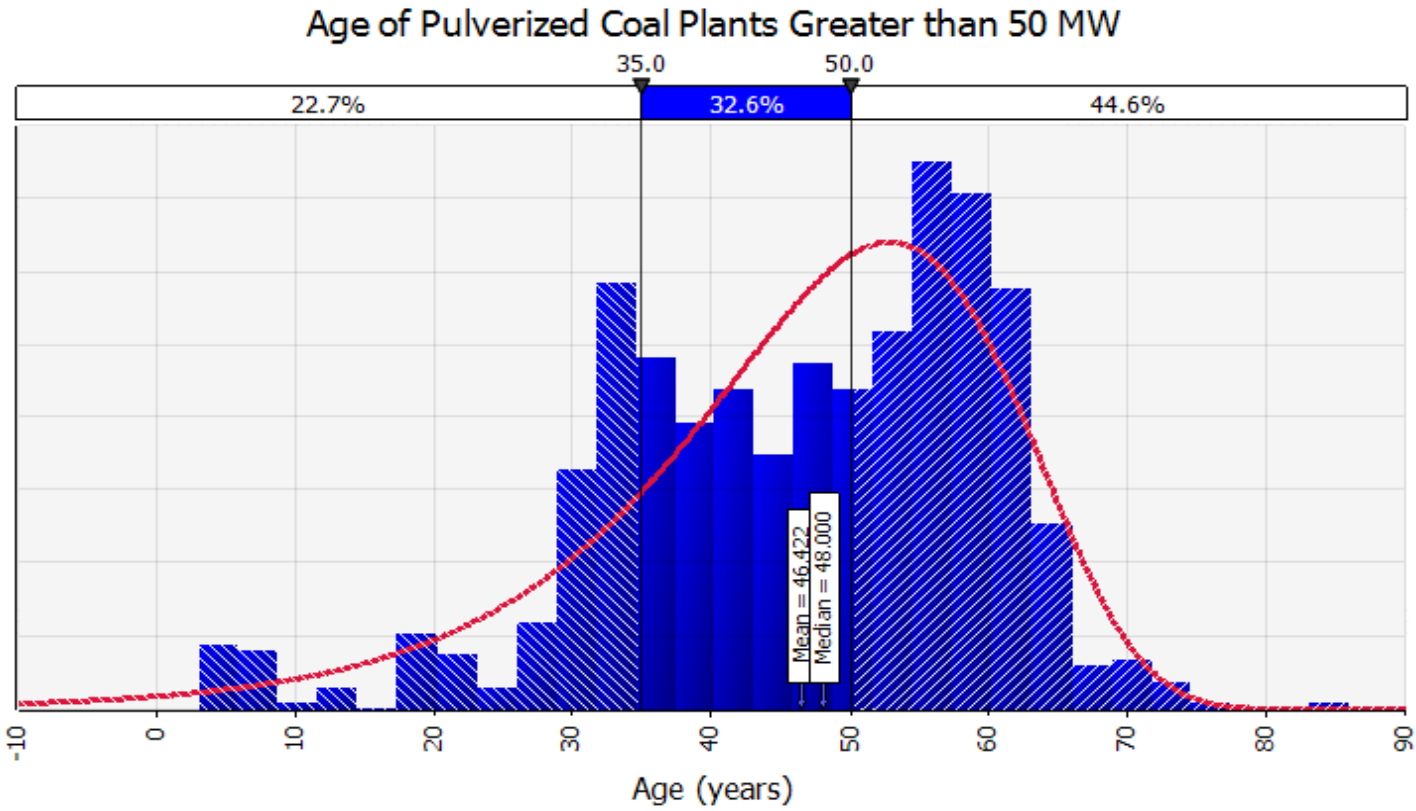
The conversion from a pulverized coal plant to a pulverized wood pellet plant is relatively straight forward. The coal plants grind the coal into dust and then pneumatically transport that dust to wall-mounted burners in the boiler. The coal dust combusts very rapidly; almost like a liquid fuel. Grinding pellets back into dust and burning them in essentially the same hardware has been proven[3] to be

[1] "Wood Pellet Fuel: A Solution to Reliable Baseload Low Carbon Electric Power Generation", May, 2014.
[2] "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
[3] The Drax 4000 MW power station in Selby, England has successfully converted and operated a 650 MW unit from coal to pellets. http://www.drax.com/

technically feasible. Furthermore, there is no de-rating of the power plant. Just as many megawatts can be generated from pellet fuel as from coal in the converted plant.

**What is the age of the pulverized coal fleet?**

The median age of a pulverized coal plant in the US is 48 years. The chart below shows the distribution of the 428 50MW or larger pulverized coal plants in the US[4].




As the chart shows, 77.3% of the plants are older than 35 years. Only 22.7% of the plants are less than 35 years old. 44.6% of the US pulverized coal plants larger than 50 MW are more than 50 years old. Most of the older plants do not comply with emissions regulations for sulfur, mercury, and NOx and are facing expensive retrofits to their flue gas cleaning systems.

**What is the total cost of generation?**

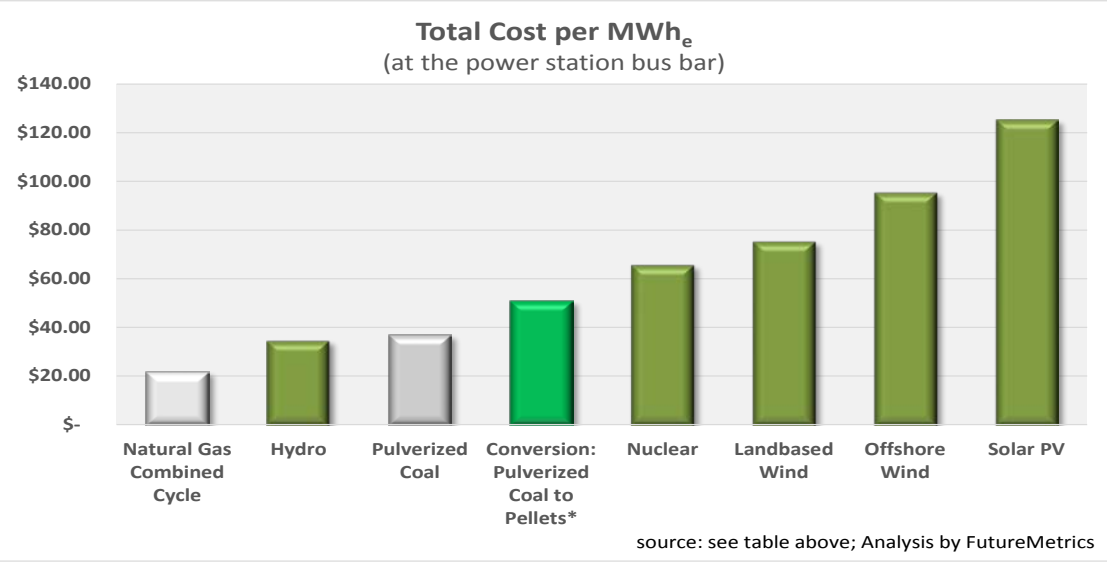
There are three broad components that add up to the total cost of generation: the capital cost to build the plant, the fixed and variable operations and maintenance (O&M) costs, and the fuel cost. The capital cost is spread over many years. In the examples below we use 35 years. Each of those costs are normalized to the cost per MWh of electricity generated ($MWh_e$). The table and chart on the following pages shows the analysis.

[4] Data is from the EPA Emissions & Generation Resource Integrated Database (eGRID), February, 2014.

| 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 $175.00 per ton | or $9.72 per MMBTU |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | at | 6.00% | | | | | |
| | Construction or Conversion Cost per kW | Size (MW) | Capacity Factor | Install Cost | Annual Capital Cost Amortization | Annual Output ($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*** | $ 3,100 | 600 | 85.0% | $ 1,860,000,000 | $ 128,291,378 | 4,467,600 | $ 28.72 | $ 5.50 | $ 16.59 | **$ 50.80** |
| **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



The table shows the assumed costs per million BTU (MMBTU) for each fuel[5]. For wood pellet fuel, the assumed cost per ton is $175[6] which equates to about $9.72/MMBTU. At these prices for fuel, wood pellet fuel is 2.88 times more expensive than coal.

**But the fuel cost is not the largest component of the total cost of generation**. If it were, then wind, solar, and nuclear, with free or very low cost fuel, would provide cheap electricity. The primary component of the total cost of generation is the amortized capital costs of building the generating facility. That is why, for example, nuclear power, with very low fuel costs, is expensive.

Thus, although pellet fuel is 2.88 times more expensive than coal, the total cost of generation with wood pellet fuel is only 1.38 times more expensive. Based on this analysis, coal power costs $36.74 per $MWh_e$ (or $0.037/$kWh_e$) versus pellet fuel power costing $50.80 per $MWh_e$ (or $0.051/$kWh_e$). Other than hydro, wood pellet fuel is by far the lowest cost low carbon baseload solution[7] for power generation. Hydro, while low cost and low carbon, has been almost fully exploited in the US and/or is not available in many locations.

Conversion to wood pellet fuel is very low-cost solution to implement since only minor modifications are necessary to the boilers. The new fuel storage and handling infrastructure are the major capital costs.

### The total cost for the power from pellet fuel is even lower than shown above

Suppose we ignore the major capital costs of any plant older than 35 years with the assumption that those costs have been recouped. Also assume that any conversion from coal to 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[8].

For this analysis the assumption is that the cost of conversion is about $210 per kilowatt (kW) of capacity. Older coal plants that do not convert to wood pellet fuel will have to install new emissions control systems. Those new capital costs and increased O&M costs are shown in the table on the next page.

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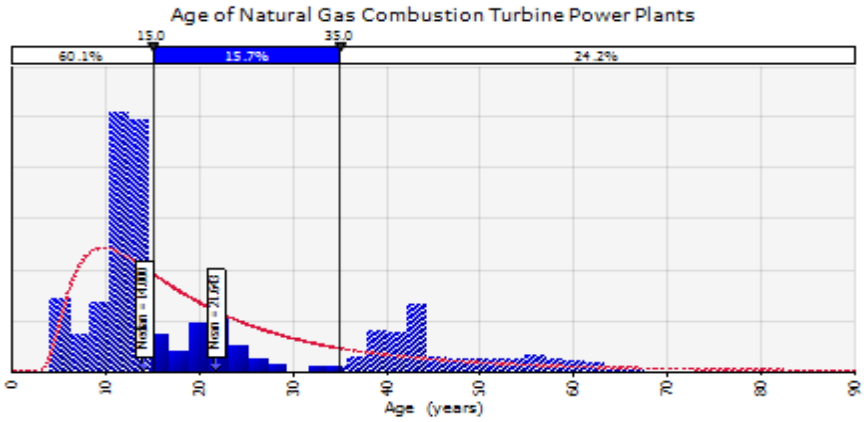
[5] Based on EIA data, May, 2014.

[6] This is slightly higher than the current FOB price for industrial pellets shipping to the UK and Western Europe. Source: Argus Biomass Markets, May 28, 2014.

[7] See FutureMetrics's papers on the sustainability of wood fuels and how, if sustainably managed, they are carbon neutral in combustion. As all fuels that need extraction, refining, and transport, they do carry a carbon footprint from those activities. www.FutureMetric.com.

[8] This logic is also true for any power plant older than 35 years. The mean age for a natural gas combustion turbine power plant is 21.6 years. The median age is 14 years. Only 24.2% are older than 35 years. Most wind is less than 10 years old (EIA, May, 2014). Nuclear and hydro plants are older. The average age of the nuclear fleet is 33 years and the hydro dams is over 50 years. (EIA, 2014).



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| **Hydro** | $ - | 1000 | 90.0% | $ - | $ - | 7,884,000 | $ - | $ 4.10 | $ - | **$ 4.10** |
| **Pulverized Coal (older than 35 years)**** | $ 380 | 610 | 85.0% | $ 231,800,000 | $ 15,988,141 | 4,542,060 | $ 3.52 | $ 5.60 | $ 5.77 | **$ 14.89** |
| **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** |
| **Conversion: Pulverized Coal to Pellets*** | $ 210 | 600 | 85.0% | $ 126,000,000 | $ 8,690,706 | 4,467,600 | $ 1.95 | $ 5.50 | $ 16.59 | **$ 24.03** |
| **Nuclear** | $ 6,100 | 1125 | 90.0% | $ 6,862,500,000 | $ 473,333,107 | 8,869,500 | $ 53.37 | $ 11.80 | $ 0.60 | **$ 65.76** |
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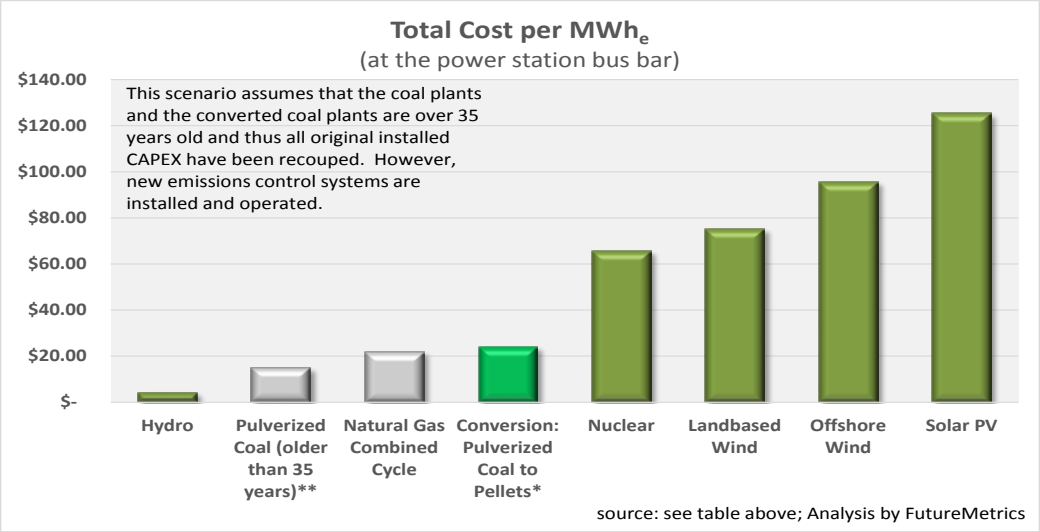
| **Solar PV** | $ 4,340 | 100 | 30.0% | $ 434,000,000 | $ 29,934,655 | 262,800 | $ 113.91 | $ 11.40 | $ - | **$ 125.31** |

*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

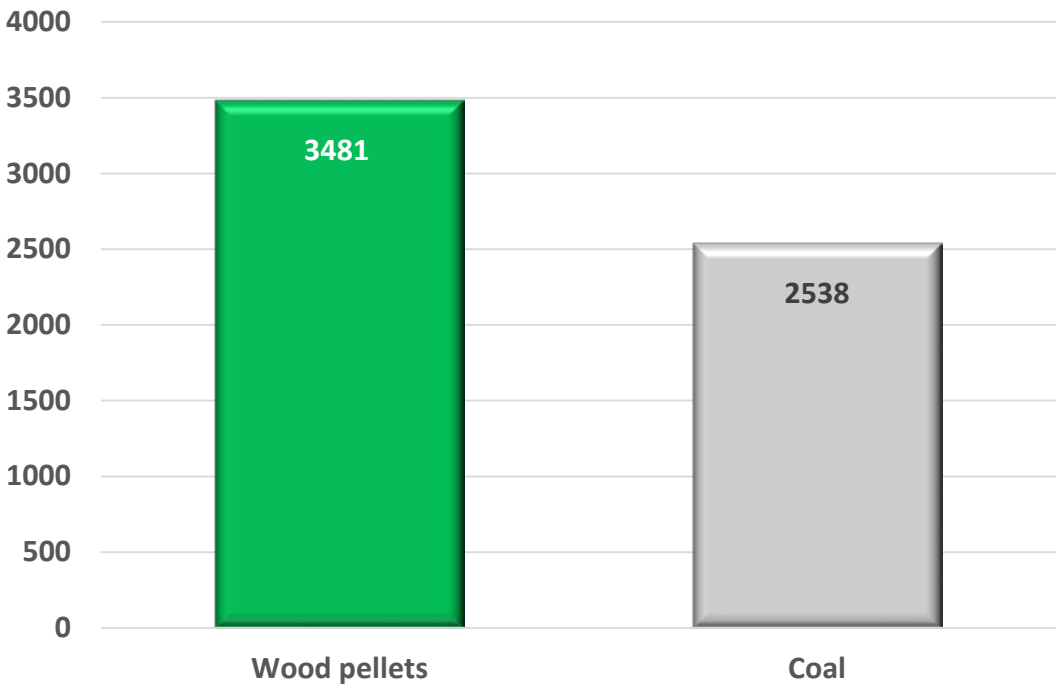


Under this scenario, converted older pulverized coal plants using pellet fuel yield almost the same total cost of generation as natural gas combined cycle plants.

### Job creation or destruction?

Pellet fuel is 2.88 times more expensive than coal for a reason. The supply chain requires more labor.

Every one million tons of wood pellets produced creates and sustains over 1800 jobs in the harvest, raw material transport, conversion into wood pellets, and transport to power plants. For each million tons of coal produced, 1320 jobs are created[9]. Coal energy content varies by type and moisture content. On average, a ton of coal has about 1.2 times more energy than a ton of wood pellets. Both the lower energy density and higher cost of production for pellets means that the number of jobs necessary to get the same energy to the power plant is higher for pellets versus coal.




Analysis on pellet 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

Converting from pulverized coal to wood pellet fuel will have a significant positive net job impact in the fuel supply chain.

The typical argument against low carbon power solutions such as wind and solar is that they will result in a higher electricity price and that this will harm industry and consumers. As the analysis above shows, wind and solar will result in significantly higher power prices. But as the analysis also shows, the difference in price between operating pulverized coal plants in compliance with emissions regulations and using the same boilers (no new emissions

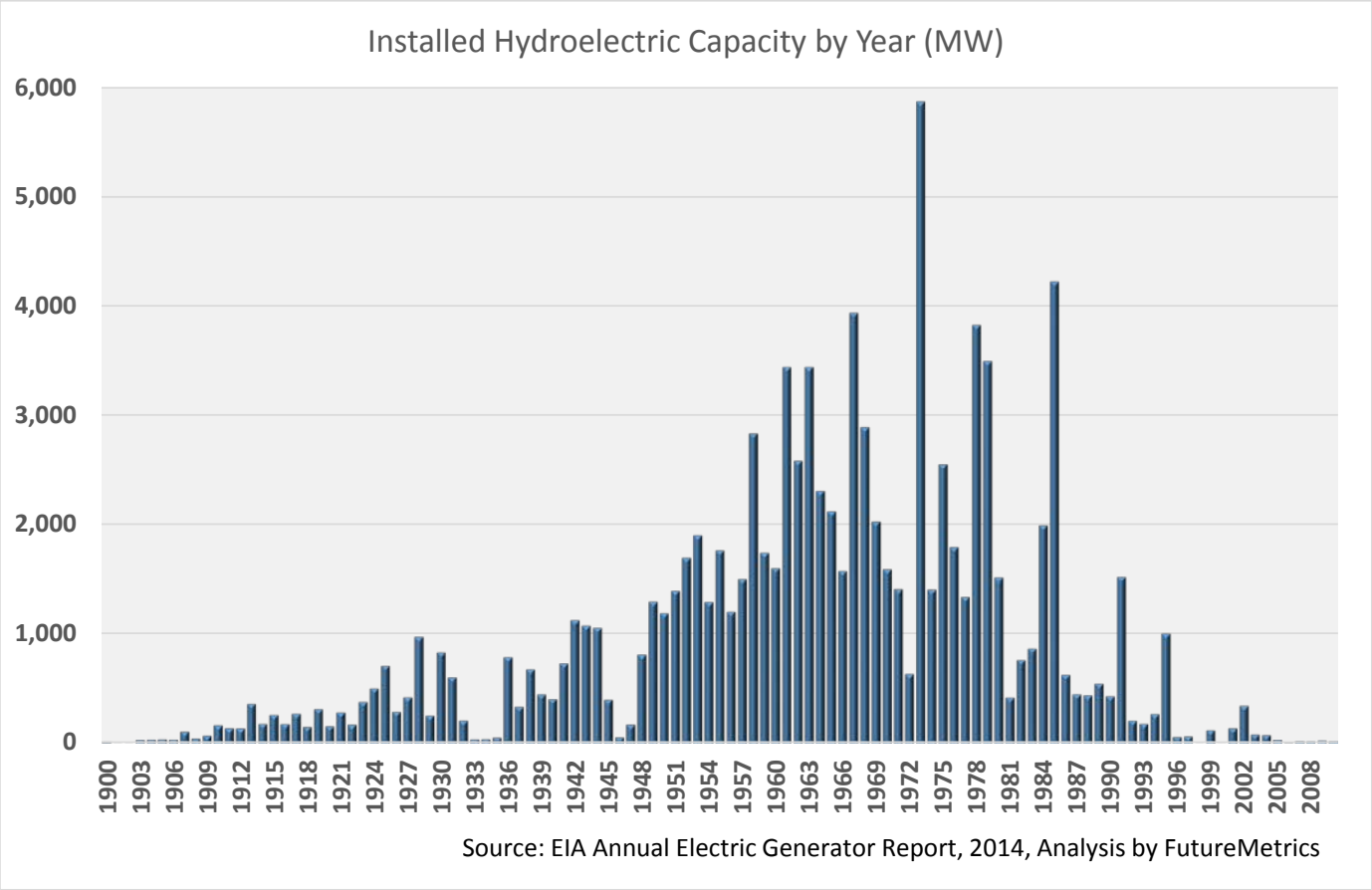
[9] Analysis on pellet jobs by FutureMetrics using IMPLAN. Data on coal employment from "U.S. Coal Exports: National and State Economic Contributions", Ernst & Young, May, 2013. Both include direct, indirect, and induced jobs.

systems needed) fueled with low carbon, zero sulfur and zero mercury wood pellet fuel is only $9.15/MWh or not even one penny per kilowatt-hour ($0.009/kWh). Small incremental energy efficiency improvements will wash out that small difference. Furthermore, other than hydro, no other low carbon power generation pathway is even close in cost per $MWh_e$.

**Conclusion**

The best solution for new low carbon power generation that has baseload characteristics is from converting older pulverized coal plants from coal to renewable low carbon wood pellet fuel.

It is unlikely that any significant new hydroelectric capacity will be built in the US. As the chart below shows, most of the significant hydro resources have been harnessed many years ago.




Source: EIA Annual Electric Generator Report, 2014, Analysis by FutureMetrics

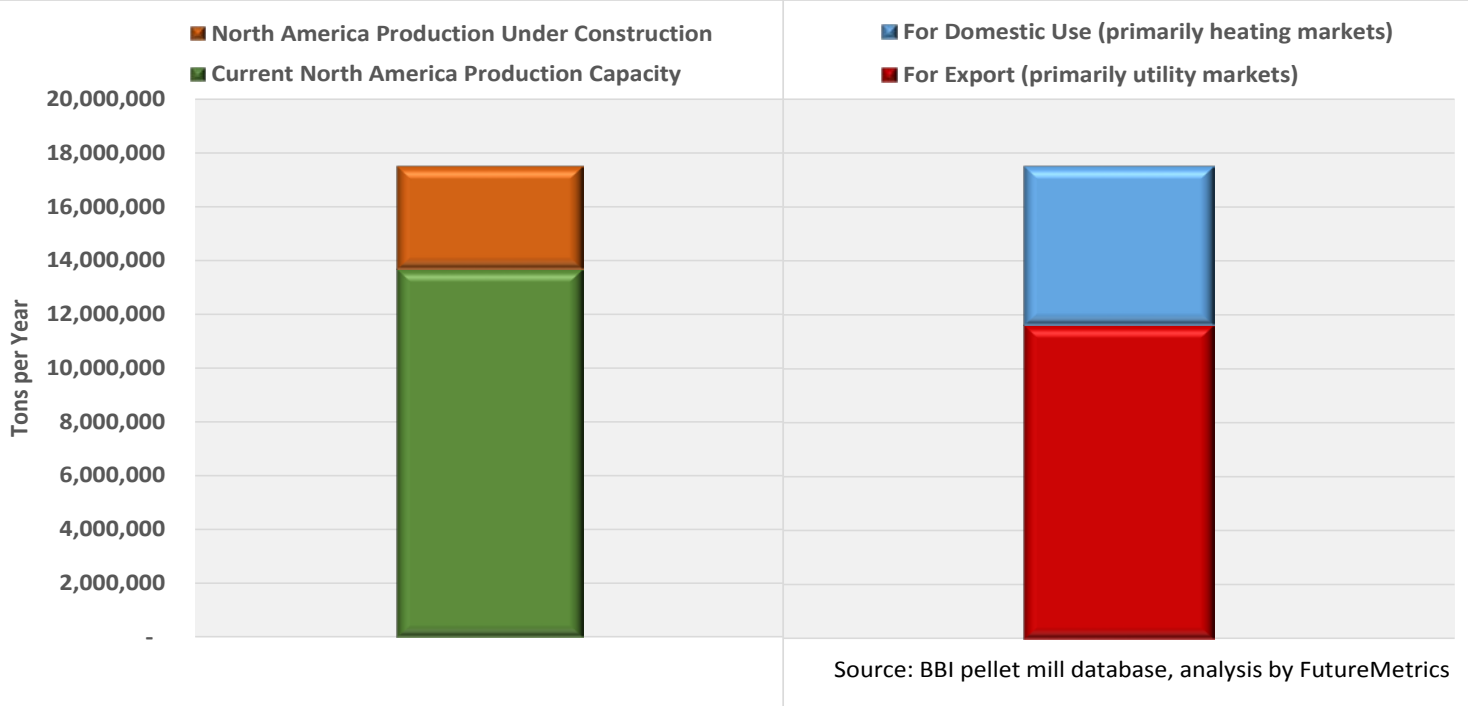
It is unlikely that the more popular sources of low carbon power, wind and solar, will solve the intermittency problem in the short to medium term. Even if large power storage solutions are developed, they will incur new capital costs that will have to be amortized over another 35 years; and that will add to the total cost of generation which is already very high.

New nuclear plants can solve the carbon emissions problem and should be a part of the menu of solutions. But the power will not be low cost and the time to startup is long. It is unlikely that new nuclear capacity will be online within the next 10 years.

As noted in our earlier papers, the quantity of power that can be generated by pulverizing renewable wood pellet fuel is limited to the sustainable quantities of wood that can be harvested for the purpose of making wood pellets.

If the power is called renewable, the fuel must renew. Within that sustainability boundary, a significant proportion of older pulverized coal plants can be converted to using low carbon wood pellets as fuel.

By mid-2015, North America will be producing and exporting nearly 12 million tons per year of pellets for power plants in the UK, Europe, and South Korea.




Source: BBI pellet mill database, analysis by FutureMetrics

Many new pellet manufacturing projects could be developed if the demand were to increase. There is no shortage of sustainable, and therefore forever renewing, feedstock in the traditional fiber baskets of the US and Canada. And with the ongoing changes in paper demand, more and more wood will be available to be converted into low carbon wood pellet fuel from working forests that are managed to produce new pellet feedstock forever.

Many pellet manufacturing projects in the US and Canada are on hold due to changes in UK policy and uncertainty over policy in Western Europe. Those projects and many others not yet conceived could supply our domestic power demands with low carbon, sustainable, and job creating fuel if the demand were to materialize.

This is a strategy that does not need R&D, does not need massive subsidies, and does not need any significant new infrastructure. As noted above, the difference in cost between an older pulverized coal plant in compliance with emissions regulations and a converted pulverized coal plant using wood pellet fuel is about $9.15/MWh or not even one penny per kilowatt-hour ($0.009/kWh).

The US cannot sufficiently mitigate carbon emissions with wood pellet fueled power stations to meet any reasonable goal for carbon reduction. There is not enough sustainable feedstock. But as part of the solution, the strategy is robust for many reasons. It is baseload, it is dispatchable, it is low cost, it creates jobs, and the infrastructure is there now. There are many wood pellet manufacturing project operators and developers that will fill the capacity gap for pellets if these conversions take place.

Although a more rigorous analysis is necessary prior to any policy recommendation, it is clear that right now there is a low cost, reliable, ready to deploy, low carbon solution to our baseload power demand that will result in the creation of more jobs than those displaced from the coal sector; all at a cost per MWh that is insignificant.