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
We can match financial needs with potential investors.

Dr. William Strauss, President, FutureMetrics

Recipient of the 2012 International Excellence in Bioenergy Award
There are basically two types of coal power stations:

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

**Pulverized** 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 into 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 not the largest component of the total cost of generation.

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

The primary component 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.
<table>
<thead>
<tr>
<th>Conversion Type</th>
<th>Construction or Conversion Cost per kW</th>
<th>Size (MW)</th>
<th>Capacity Factor</th>
<th>Install Cost</th>
<th>Annual Output (MWhᵃ)</th>
<th>Fixed Capital Cost per MWhₑ</th>
<th>Fixed and Variable O&amp;M per MWhₑ</th>
<th>Fuel Cost per MWhₑ</th>
<th>Total Cost per MWhₑ (at the power station bus bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas Combined Cycle</td>
<td>$1,230</td>
<td>580</td>
<td>90.0%</td>
<td>$713,400,000</td>
<td>$49,205,951</td>
<td>$4,572,720</td>
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<tr>
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<td>$6,862,500,000</td>
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<td>-</td>
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<td>$262,800</td>
<td>$11.40</td>
<td>-</td>
<td>$125.31</td>
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</tbody>
</table>

*Assumes CAPEX of coal plant plus conversion costs


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


<table>
<thead>
<tr>
<th></th>
<th>Construction, Conversions and New Pollution Control Cost for Coal Plant per kW</th>
<th>Size (MW)</th>
<th>Capacity Factor</th>
<th>Install Cost</th>
<th>Annual Capital Cost Amortization</th>
<th>Annual Output (MWhₑ)</th>
<th>Fixed Capital Cost per MWhₑ</th>
<th>Fixed and Variable O&amp;M per MWhₑ</th>
<th>Fuel Cost per MWhₑ</th>
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<tr>
<td>Hydro</td>
<td>$ -</td>
<td>1000</td>
<td>90.0%</td>
<td>$ -</td>
<td>$ -</td>
<td>7,884,000</td>
<td>$ -</td>
<td>$ 4.10</td>
<td>$ -</td>
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<tr>
<td>Pulverized Coal (older than 35 years)**</td>
<td>$ 380</td>
<td>610</td>
<td>85.0%</td>
<td>$ 231,800,000</td>
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<td>$ 5.25</td>
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<td>$ 16.62</td>
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<td>Natural Gas Combined Cycle</td>
<td>$ 1,230</td>
<td>580</td>
<td>90.0%</td>
<td>$ 713,400,000</td>
<td>$ 73,453,636</td>
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<td>600</td>
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<td>$ 170.04</td>
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<td>$ 181.44</td>
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</table>

*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.

Green shading for low carbon solutions

Utility Natural Gas at $5.50 per MMBTU or $8.61 per MMBTU

Coal at $2.60 per MMBTU

Wind, at 6.00%

Costs amortized over 15 years

$155.00 per ton of $2.60 per MMBTU

Pellets at $155.00 per ton of $5.50 per MMBTU

Electricity generated from pellets is cheaper than generating with wood chips.
Total Cost per MWh$_e$
(at the power station bus bar)

This scenario assumes that the coal plants and the converted coal plants are over 35 years old and thus all original installed CAPEX have been recouped. However, new emissions control systems are installed and operated.

Renewables and Low Carbon Pathways in Green

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.

![Bar chart showing total jobs created to supply fuel to a 500 MW power plant.](chart.png)

- **Wood pellets**: 3481 jobs
- **Wood chips**: 3276 jobs
- **Coal**: 2538 jobs

*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.*

- Hundreds of high paying pellet mill jobs to convert wood to pellets
- More trucking jobs to move chips vs pellets or coal to the power station
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!
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