Overview of Global Pellet Markets and

Micro-Scale Pellet-Fueled Combined Heat and Power: A new distributed power solution for the smart grid of the future

By William Strauss, PhD, FutureMetrics

The New Forest Economy- Biobased Power, Products, & Fuels
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FutureMetrics

Intelligent Analysis and Strategic Leadership for the Pellet Sector

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Recipient of the 2014 International Founders Award
Overview of Global Pellet Markets

Putting this into perspective
Global wood pellet markets have had significant growth in the past decade. The wood pellet market has experienced growth rates over the last few years of about 10% annually from about 19.5 million metric tonnes in 2012 to about 28 million metric tonnes in 2015.

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</tr>
</thead>
<tbody>
<tr>
<td>Europe</td>
<td>19,469,000 tonnes</td>
<td>13.5%</td>
<td>22,096,000 tonnes</td>
<td>15.4%</td>
<td>26,154,000 tonnes</td>
<td>6.9%</td>
<td>27,969,000</td>
</tr>
<tr>
<td>Asia</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>5,697,000 tonnes</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Americas</td>
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<td></td>
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<tr>
<td></td>
<td>3,200,000 tonnes</td>
<td></td>
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<tr>
<td>Rest of World</td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>2,690,000 tonnes</td>
<td></td>
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</table>

Source: Data from Food and Agriculture Organization of the United Nations, December, 2016, Analysis by FutureMetrics
There are Two Categories of Wood Pellets:

• For use in pellet stoves and pellet boilers for heat (premium heating pellets)

• For use as a substitute for coal in large utility power plants (industrial pellets)
Global Wood Pellet Demand
(Thousands of metric tonnes)

Forecast ==> 4,900 4,700 7,900 9,600 10,000 11,600 14,000 17,300 22,500 27,200 29,800 32,600 34,800 37,600 40,200 42,000

Sources: Argus Biomass Direct data, European Pellet Council, HPBA stove data; Analysis and Forecast by FutureMetrics.
**Industrial Wood Pellets**

Why Wood Pellets are an Easy Substitute for Coal in Pulverized Coal (PC) Power Plants

- Wood pellets are **upgraded solid fuel** made from biomass.
- They are grindable.
- They are dry (~5% moisture content).
- They handle easily.
- They have an energy density of ~18 Gigajoules/tonne.

At low co-firing ratios (less than ~6% white wood pellets) no modifications are required.

At higher blend ratios modifications are needed but they are well understood and proven in large PC plants.
Industrial Wood Pellet Demand Forecast for the Europe, the UK, Korea, Japan, and Canada

(Thousands of metric tonnes)

UK  Netherlands  Belgium  Denmark  Sweden  Other  Korea  Japan  Canada

Source: Historical data from Argus Direct, forecast and analysis by FutureMetrics

Average Growth from 2010 to 2025 is 2,740,000 Metric Tonnes per Year
What is driving the industrial wood pellet markets?

This is what is driving policy in every other developed country in the world except the US.

Source: EPA's Climate Change Indicators in the United States: [www.epa.gov/climate-indicators](http://www.epa.gov/climate-indicators), March, 2017, analysis by FutureMetrics
CO₂ Released from Fossil Fuel Combustion

Global Land and Ocean Temperature Anomalies

Source: NOAA, March 2017; Analysis and time series trend by FutureMetrics


Drax Power Station in the UK – Six 645 MW lines: three running on 100% wood pellet fuel

- 3 unit conversion
- No impact on efficiency and no loss of output
- Flexible output from 200MW to 645MW per unit

7.5 million metric tonnes per year of industrial wood pellets
Heating Pellets Markets

Global Premium (heating) Pellet Demand (Residential and Commercial) in 1000's Metric Tonnes

About 9 million tonnes per year increase

FutureMetrics - Globally Respected Consultants in the Wood Pellet Sector
Micro-Scale Pellet-Fueled Combined Heat and Power:

A new distributed power solution for the smart grid of the future
The New Combined Heat and Power System

The new micro-CHP system is built upon the foundation of the reliable and highly efficient OkoFEN pellet boilers. There are more than 60,000 OkoFEN pellet boilers installed in 17 countries. In the US, thousands of systems produced in Maine by Maine Energy Systems are heating homes, businesses, municipal buildings, schools, and other buildings.

These fully automatic pellet boilers have proven their reliability and efficiency.

Now, in addition to heat, the pellet-fueled micro-CHP boiler also generates electricity.

After several years of R&D and field testing, the micro-CHP systems are being deployed in Europe and are several months from full approval for sale in the US.
The micro-CHP boiler produces up to 60 kilowatts of heat (about 205,000 BTU/hour) and up to 5 kilowatts of electricity. So, while the building is being heated by pellets, the CHP unit is also generating electricity.

The entire system sits on a space that is about 40 inches by 36 inches (100cm x 90cm).
How the Stirling engine and generator work.

1. The head of the Stirling engine is heated with the flame of the wood pellet fuel. The heat is then transferred to the working fluid of the Stirling engine (helium). The heating leads to a pressure increase.

2. With the heat supply and the cooling of the Stirling engine from return water in the heating loop, a temperature and pressure difference is generated. Through this temperature difference, the helium in the Stirling engine expands and contracts in a cycle and the piston is set in motion moving up and down 60 times per second.

3. This movement is converted by the linear generator inside the Stirling engine into 60 cycle AC electricity.
With the default inputs for the dashboard and comparing a gasoline fueled car with the BMW i3 EV, it is **5.45 times costlier in the US to drive the same distance in a combustion engine car running on gas than it is with the EV charged by the micro-CHP.**

Or to put in another way, gas would have to cost about $0.40/gallon for the two costs per mile to be equivalent.
A Vision of How Micro-CHP will be Part of the Smart Grid and Invigorate the Market for Wood Pellets

Based on EIA and US census data, Maine has the lowest proportion of homes and business connected to natural gas (5.8%).

Because natural gas infrastructure does not reach most of Maine’s small towns and rural areas, Maine has the highest dependency on heating oil and propane of any state in the US. Maine also has the highest proportion of people living in rural areas (61.3%) than any other state.

Most of Maine’s occupied buildings will never connect to a natural gas pipeline.
Furthermore, Maine has suffered major losses in the pulp and paper sector over the last few years.

“It’s no secret that Maine has lost pulp mills in recent years. Bucksport, East Millinocket, Lincoln, Old Town, and Madison are now gone. The storied Androscoggin Mill in Jay is now a shadow of its former self (as measured by wood use), with Verso having moved beyond its “Skinny Andro” plan to something even leaner. Across these mills, Maine has lost somewhere around 3 million tons of pulpwood (and mill chip) markets since 2014. Put another way, the market has shrunk by 275 loads per day, every day. That doesn’t count the biomass markets lost at these mills.”*

*From an article by Eric Kingsley, Innovative Natural Resource Solutions, in The Northern Logger and Timber Processor Magazine, February 2017
If we assume that 20% of the estimated 262,000 occupied buildings in Maine not on natural gas are large enough to have a demand of 205,000 BTU/hour or more, and that they install the OkeFEN/MESys pellet-fueled CHP systems over the next several years, there would be about 52,400 micro-CHP systems providing heat and power in Maine.

If the average output of electricity per unit over the heating season is 2.5 kW’s, the average output from all of those systems would be about 131 megawatts. At peak power output during the cold winter months when the micro-CHP is outputting 5 kW’s, the 52,400 units would be generating 262 MW’s.

The aggregated distributed power production would make the top ten list of power plant capacities in Maine; and during the cold winter months, the top five (the top four if Wyman is excluded).

<table>
<thead>
<tr>
<th>Plant</th>
<th>Primary energy source</th>
<th>Operating company</th>
<th>Net summer capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>William F Wyman</td>
<td>Petroleum</td>
<td>FPL Energy Wyman LLC</td>
<td>811</td>
</tr>
<tr>
<td>Westbrook Energy Center Power Plant</td>
<td>Natural gas</td>
<td>Westbrook Energy Center</td>
<td>506</td>
</tr>
<tr>
<td>Maine Independence Station</td>
<td>Natural gas</td>
<td>Casco Bay Energy Co LLC</td>
<td>490</td>
</tr>
<tr>
<td>Bucksport Generation LLC</td>
<td>Natural gas</td>
<td>Verso Bucksport LLC</td>
<td>274</td>
</tr>
<tr>
<td>Rumford Power, Inc</td>
<td>Natural gas</td>
<td>Rumford Power</td>
<td>254</td>
</tr>
<tr>
<td>Oakfield Wind Project</td>
<td>Wind</td>
<td>First Wind O&amp;M, LLC</td>
<td>148</td>
</tr>
<tr>
<td>Androscoggin Energy Center</td>
<td>Natural gas</td>
<td>Verso Paper Androscoggin LLC</td>
<td>137</td>
</tr>
<tr>
<td>Kibby Wind Power Project</td>
<td>Wind</td>
<td>TransCanada Maine Wind Development Inc</td>
<td>132</td>
</tr>
<tr>
<td>Great Lakes Hydro America - ME</td>
<td>Hydroelectric</td>
<td>Great Lakes Hydro America LLC</td>
<td>132</td>
</tr>
<tr>
<td>Somerset Plant</td>
<td>Wood</td>
<td>Sappi Fine Paper North America-Somerset</td>
<td>115</td>
</tr>
</tbody>
</table>

Most of those MW’s would replace power generated from natural gas transported to Maine from far away with fuel made in Maine.

And all the heat that the micro-CHP systems produce would replace heat produced from heating oil and propane with heat produced from pellet fuel made in Maine.

Each unit would use about 30 tons of wood pellets per year.

Aggregate demand under this scenario would be about 1.56 million tons per year.

1.56 million tons per year may sound inconceivable for Maine which only has current pellet production capacity of about 300,000 tons per year.

But that 3 million tons per year of wood chips that pulp mills in Maine have been taking in for generations, but are no longer using (and never will again), could produce about 1.65 million tons per year of wood pellets; enough to fulfill this vision for the future.

Furthermore, many of the jobs that have been lost would return.
Compare Capital Cost per actual kWh with Fuel Cost per kilowatt-hours per year.

- **Rooftop solar at installed cost of $3.50 per watt and at a 16% capacity factor. Zero fuel cost per kWh.**
- **Micro-CHP at installed cost of $0.72 per watt running 50% of the total hours per year and 4.0 kW average power output when running. Fuel cost = $0.062 per kWh.**

**Capital cost per Effective kWh:**
- Rooftop solar: $35,000
- Micro-CHP: $30,000

**Yearly Duration:**
- 25 years
<table>
<thead>
<tr>
<th>State/Area</th>
<th>Number of Plants</th>
<th>Installed Capacity MW</th>
<th>Average MW Per Plant</th>
<th>Generation GWh</th>
<th>Capacity Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>289</td>
<td>4,395</td>
<td>15.3</td>
<td>10,826</td>
<td>28.1</td>
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<tr>
<td>Arizona</td>
<td>48</td>
<td>1,078</td>
<td>22.5</td>
<td>2,550</td>
<td>27.0</td>
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<tr>
<td>Nevada</td>
<td>11</td>
<td>238</td>
<td>21.6</td>
<td>557</td>
<td>26.7</td>
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<tr>
<td>New Mexico</td>
<td>33</td>
<td>261</td>
<td>7.9</td>
<td>590</td>
<td>25.8</td>
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<tr>
<td>Colorado</td>
<td>20</td>
<td>118</td>
<td>5.9</td>
<td>235</td>
<td>22.7</td>
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<tr>
<td>Texas</td>
<td>12</td>
<td>187</td>
<td>15.6</td>
<td>354</td>
<td>21.7</td>
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<tr>
<td>North Carolina</td>
<td>148</td>
<td>669</td>
<td>4.5</td>
<td>1,162</td>
<td>19.8</td>
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<tr>
<td>New York</td>
<td>13</td>
<td>53</td>
<td>4.1</td>
<td>84</td>
<td>18.2</td>
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<tr>
<td>Indiana</td>
<td>24</td>
<td>94</td>
<td>3.9</td>
<td>149</td>
<td>18.1</td>
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<tr>
<td>Maryland</td>
<td>17</td>
<td>67</td>
<td>3.9</td>
<td>101</td>
<td>17.2</td>
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<td>Vermont</td>
<td>14</td>
<td>28</td>
<td>2.0</td>
<td>41</td>
<td>16.9</td>
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<tr>
<td>Ohio</td>
<td>12</td>
<td>38</td>
<td>3.2</td>
<td>56</td>
<td>16.7</td>
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<td>New Jersey</td>
<td>116</td>
<td>409</td>
<td>3.5</td>
<td>597</td>
<td>16.7</td>
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<td>295</td>
<td>2.6</td>
<td>416</td>
<td>16.1</td>
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<td>Pennsylvania</td>
<td>19</td>
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<td>2.5</td>
<td>64</td>
<td>15.5</td>
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<tr>
<td>Other States</td>
<td>56</td>
<td>288</td>
<td>5.1</td>
<td>488</td>
<td>19.3</td>
</tr>
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</table>
This transition cannot happen overnight.

But there is nothing in this strategy that is not possible.

- The technology exists,
- The sustainable wood supply exists,
- The economics for producing heat and power from pellet fuel makes sense, and
- Maine needs a way to revitalize its forest products industry.

Over the next decade, Maine could achieve this vision.
Some analysts predict that all new cars will be electric vehicles by 2035.

Perhaps well before that, for those of us that live in the parts of the world that have cold winters and well-managed and underutilized working forests, micro-CHP fueled by low carbon renewable locally produced pellet fuel will be supplying some of the electricity that will drive us to work.

Thank you!

Bill Strauss