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"Black Pellets" – A Financial Analysis of Costs and Benefits:

Can they provide cheaper energy than white pellets?

By William Strauss, July, 2014

This white paper will deconstruct the components of the benefits and costs of "black pellets". It will compare torrefied pellets and steam exploded pellets with traditional white pellets[1].

There is very limited data on actual capital costs and operating costs for commercial scale production facilities. Therefore the model used in this analysis is based on a number of estimates and assumptions based on publicly available sources[2]. Some of the estimates and assumptions may not precisely match data from the suppliers of these technologies. In particular, there is very limited information on the capital costs (capex) and operating costs (opex) of plants that include these technologies. Where the estimates for costs have a significant impact on the analysis we show the sensitivity of the outcomes to changes in those estimates.

In this analysis we do not look at the cost per tonne. We look at the cost per unit of energy produced for the end user. The utility buyers of pellets of any color are buying energy. The unit of measure for energy that we use in this analysis is gigajoules (GJ). Typical offtake agreements include a prorated add-on for energy densities greater than a baseline (often 17 to 17.5 GJ/tonne). So higher energy density pellets command a higher price. If the increase in the cost of production per GJ is less than the increase in the price per GJ, then the technology is economically viable. We will compare the benefits in $/GJ of shipping white and black pellets with the costs of production.

This analysis will use white pellets as the benchmark and will calculate the net benefit or penalty of producing torrefied or steam exploded pellets versus white pellets. The analysis will first calculate the value of a shipload of white, torrefied, and steam exploded pellets delivered to a foreign port. It will then calculate the additional costs required to manufacture white, torrefied, and steam exploded pellets. Subtracting the costs per GJ from the value per GJ will provide the final metric which will determine if there is a valid economic argument for torrefaction and steam explosion.

There are other characteristics of black pellets not embodied in the $/GJ metric. Some black pellets are water resistant or waterproof. Black pellets pulverize with less energy than white pellets. However for this analysis, those characteristics are not quantified. This analysis only looks at the input costs per GJ, shipping costs per GJ, and what utilities are willing to pay for a GJ of energy in the fuel.

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[1] Data used in this analysis is from conference presentations and non-confidential documentation by major equipment suppliers in the pellet sector who have developed and demonstrated at commercial scale technology for torrefaction and steam explosion; and from data on white pellets gathered by FutureMetrics from many pellet manufacturers. FutureMetrics has not independently verified the "black" pellet data used in this analysis.

[2] A few of the more important sources are: "Enhanced Biomass Alternatives: A Comparison of Torrefaction and Steam Explosion Technologies", Presented at the International Biomass Conference, Orlando, March, 2014 by Brian Greenwood, Andritz ; "Torrefaction", presented at the World Biomass Power Markets Conference, Amsterdam, February, 2014 by Andrew Johnson, TSI; and "Zilkha Black Pellets Handling, Storage and Grinding in Existing Coal Plants", presented at the World Biomass Power Markets Conference, Amsterdam, February, 2014.

Higher Bulk and Energy Density put significantly more GJ on a Ship

Both torrefaction and steam explosion result in higher energy density and higher bulk density pellets. In both processes, a comparison of the incoming wood and final densified product shows that the loss of mass is greater than the loss of energy. That change in bulk and energy densities is advantageous to logistics. More tonnes per unit of volume and more energy per tonne lowers the delivery cost per unit of energy.

The analysis will assume that the buyer is willing to pay the same price per GJ for any of the three types of pellets. Using an assumed price of $160 per metric tonne FOB for white pellets[3] and using the energy densities in the table below, the value of a GJ FOB is $9.41.

	Energy (GJ/tonne)
White	17.0
Torrefied	22.0
Steam Exploded	19.5

The bulk densities of the three types of pellets are shown in the table below.

	Bulk Density (kg/m^3)
White	650
Torrefied	675
Steam Exploded	750

The assumed volume of the ship that is loaded with pellets is 60,000 cubic meters. For all three types of pellets the ship will "cube out" (fill up completely) before reaching a maximum weight limit. The table below shows the tonnes and GJ that would be loaded on a 60,000 m^3 ship. The steam exploded pellets make the heaviest load and the torrefied pellets pack the most energy on the ship.

	GJ/m^3	Vessel volume (m^3)	Tonnes on board	GJ on board
White	11.05	60,000	39,000	663,000
Torrefied	14.85	60,000	40,500	891,000
Steam Exploded	14.63	60,000	45,000	877,500

[3] Based on Argus Biomass Markets report, July 23, 2014, bid spot price, southeast US.

Assuming a shipping cost of $17/tonne[4] for a 45,000 tonne load of steam exploded pellets, the estimated costs per tonne for shipping pellets are shown below. The lower bulk density pellets incur higher shipping costs per tonne. The higher energy density of the torrefied pellets yields a lower cost per GJ for shipping.

	shipping cost per tonne	Shipping cost per GJ	Fines Loss Cost per GJ
White	$19.62	$ 1.154	$0.013
Torrefied	$18.89	$ 0.859	$0.017
Steam Exploded	$17.00	$ 0.872	$0.006

The table above also accounts for losses due to breakage (fines). The literature on fines produced from torrefied and steam exploded pellets is limited and in some cases contradictory. This analysis assumes the following losses before delivery to the carrier at the foreign port.

	Fines
White	1.5%
Torrefied	1.5%
Steam Exploded	0.5%

The table below shows the total value of the delivered fuel for each of the three types of pellets based on an FOB price of $9.41/GJ minus shipping costs and fines losses.

	Net value of pellets at foreign port in $/GJ	Margin over White per GJ at the Foreigh Port
White	$8.245	$0.000
Torrefied	$8.536	$0.291
Steam Exploded	$8.534	$0.289

As would be expected, the value of a delivered 60,000 m^3 shipload of higher bulk and energy density fuel is higher than for white pellets. The table below shows by how much.

[4] Based on Argus Biomass Markets report, July 23, 2014, to ARA (Amsterdam, Rotterdam, Antwerp) from Savannah, GA for a 45,000 tonne shipment on a vessel.

	Net value of pellets at foreign port	Margin over white pellets
White	$5,381,400	$0
Torrefied	$7,495,094	$2,113,694
Steam Exploded	$7,449,226	$2,067,826

Does the Higher Cost to Produce Negate the Shipping Advantage?

Producing torrefied and steam exploded pellets requires higher costs. The components of those costs are discussed in the following paragraphs.

The higher energy densities require a higher input of pellet feedstock into the front end of the process. Both processes also use energy in the conversion to "black" pellets. The torrefaction process requires heat, and the steam explosion process requires pressurized steam. The manufacturer of the operating commercial scale torrefaction system that is used as a basis in this analysis uses no additional wood (or other fuel) for reactor heat. Once up to operating temperatures, the VOCs in the reactor offgas are sufficient to operate the reactor without additional fuel. We have no data on the ability of the by-products of steam explosion to fuel the steam generation process. For this analysis we will run the analysis with the assumption that no additional fuel is needed. In the next section of this report below we show the sensitivity of the outcomes to changes in that assumption and a well as other assumptions.

The table below[5] shows the wood demands at an assumed moisture content of 50% for green wood and hog fuel, and 5% for the finished pellets. (ODT = "oven dry tonne" which would be the weight of the wood with 0% moisture content.)

Per tonne of pellets - feedstock and fuel at 50% and pellets at 5% moisture content	Torrefied	Steam Exploded	White
Dryer fuel consumption (odt)	0.127	0.111	0.095
Steam consumption (tonnes)	0.000	1.406	0.000
Additional Wood for steam production or for the torrefaction reaction (odt)	0.000	0.000	0.000
Wood going into the reactor (odt)	1.266	1.109	0.000
Total wood to make a tonne of pellets (odt)	1.392	1.220	1.045
Green Wood needed to make a tonne of pellets	**2.784**	**2.441**	**2.090**

Note that the higher wood input needed for the higher bulk and energy density pellets requires more wood for pre-drying than white pellets.

[5] The values in the table are based assumptions on wood energy content and process efficiency that may vary by location and process. The bottom line values will be different for different locations and technologies. The values are within a reasonable margin of error.

The table below shows the wood costs to fill a 60,000 m^3 ship based on feedstock at $36/green tonne. Dryer fuel, and if needed, reactor and steam generator fuel, are at $20/green tonne. It also shows the wood cost per GJ.

	Tonnes on board	Wood Cost	GJ on board	Wood Cost per GJ
White	39,000	$2,815,800	663,000	$4.247
Torrefied	40,500	$3,895,594	891,000	$4.372
Steam Exploded	45,000	$3,794,063	877,500	$4.324

Additional O&M costs are assumed for the torrefaction and steam explosion processes. In both cases this analysis assumes an additional cost for O&M, including electricity, of $2.00/tonne. The table below shows those additional costs per GJ.

	O&M per tonne	GJ/tonne	O&M costs per GJ
White	$22.00	17.0	$1.294
Torrefied	$24.00	22.0	$1.091
Steam Exploded	$24.00	19.5	$1.231

The increase in capital costs also have to be accounted for. The cost of the project per installed tonne per year of capacity for a white pellet plant averages about $210. FutureMetrics has very limited data on the extra capital cost for adding the reactors and other equipment needed for both processes. For this analysis the assumption is that cost per tonne of capacity per year for the hardware for a torrefied and a steam exploded plant is about $255. Amortizing per tonne cost over 15 years using a 7.0% discount rate yields the per tonne values shown in the table below.

	Amortized capex per tonne	Amortized Capex per GJ
White	$23.06	$1.356
Torrefied	$28.00	$1.273
Steam Exploded	$28.00	$1.436

The total of these additional costs compared to the delivered value of the product are as shown in the table below. The net benefit leaves room for other costs and profits.

	Value of Delivered Pellets		Total Cost per GJ		Net Benefit Per GJ
White	$8.245	-	$6.897	=	$1.347
Torrefied	$8.536		$6.736		$1.800
Steam Exploded	$8.534		$6.990		$1.544

The net benefit over white pellets is shown in the table below.

	Net Benefit over White Pellets per GJ
White	$0.000
Torrefied	$0.453
Steam Exploded	$0.196

As noted above, this analysis does not include other potentially valued characteristics such as hydrophobicity and improved grindablity.

Sensitivity Analyses

The analysis above assumes the projects are purchasing clean white chips for $36/tonne (green) for pellets and low grade hog fuel for the dryer and, if needed, for torrefaction and steam generation, at $20/tonne (green). As the three tables below show, the advantage for torrefied and steam exploded pellets survives higher feedstock and fuel costs better than white pellets (in terms the net benefit in $/GJ). If wood costs go up for black pellets they go up for white pellets as well.

The metric in the table below is the net benefit in $/GJ. Within that net benefit are profits. A value of zero would mean the project returns no excess cash flows after costs. Each project has different debt/equity structures and different expectations for returns. FutureMetrics can provide specific project modeling on meeting hurdle rates; but for this analysis, it is not included in the table below.

The darker shaded cells in the tables below show the outcomes at the intersections of the assumptions used in the previous section of this paper.

Torrefied Pellets - Net Benefit in $/GJ - Sensitivity to Wood Costs

Hog Fuel Cost per Tonne (green)

Pellet Feedstock Cost per Tonne (green)	$18.00	$20.00	$22.00	$24.00	$26.00	$28.00	$30.00	$32.00	$34.00	$36.00	$38.00	$40.00	$42.00
$34.00	$2.05	$2.03	$2.01	$1.98	$1.96	$1.94	$1.92	$1.89	$1.87	$1.85	$1.82	$1.80	$1.78
$36.00	$1.82	**$1.80**	$1.78	$1.75	$1.73	$1.71	$1.68	$1.66	$1.64	$1.62	$1.59	$1.57	$1.55
$38.00	$1.59	$1.57	$1.55	$1.52	$1.50	$1.48	$1.45	$1.43	$1.41	$1.39	$1.36	$1.34	$1.32
$40.00	$1.36	$1.34	$1.32	$1.29	$1.27	$1.25	$1.22	$1.20	$1.18	$1.16	$1.13	$1.11	$1.09
$42.00	$1.13	$1.11	$1.09	$1.06	$1.04	$1.02	$0.99	$0.97	$0.95	$0.93	$0.90	$0.88	$0.86
$44.00	$0.90	$0.88	$0.86	$0.83	$0.81	$0.79	$0.76	$0.74	$0.72	$0.70	$0.67	$0.65	$0.63
$46.00	$0.67	$0.65	$0.63	$0.60	$0.58	$0.56	$0.53	$0.51	$0.49	$0.47	$0.44	$0.42	$0.40
$48.00	$0.44	$0.42	$0.40	$0.37	$0.35	$0.33	$0.30	$0.28	$0.26	$0.24	$0.21	$0.19	$0.17
$50.00	$0.21	$0.19	$0.17	$0.14	$0.12	$0.10	$0.07	$0.05	$0.03	$0.01	-$0.02	-$0.04	-$0.06
$52.00	-$0.02	-$0.04	-$0.06	-$0.09	-$0.11	-$0.13	-$0.16	-$0.18	-$0.20	-$0.22	-$0.25	-$0.27	-$0.29
$54.00	-$0.25	-$0.27	-$0.29	-$0.32	-$0.34	-$0.36	-$0.39	-$0.41	-$0.43	-$0.46	-$0.48	-$0.50	-$0.52
$56.00	-$0.48	-$0.50	-$0.52	-$0.55	-$0.57	-$0.59	-$0.62	-$0.64	-$0.66	-$0.69	-$0.71	-$0.73	-$0.75
$58.00	-$0.71	-$0.73	-$0.75	-$0.78	-$0.80	-$0.82	-$0.85	-$0.87	-$0.89	-$0.92	-$0.94	-$0.96	-$0.98

Steam Exploded Pellets - Net Benefit in $/GJ- Sensitivity to Wood Costs

Hog Fuel Cost per Tonne (green)

Pellet Feedstock Cost per Tonne (green)	$18.00	$20.00	$22.00	$24.00	$26.00	$28.00	$30.00	$32.00	$34.00	$36.00	$38.00	$40.00	$42.00
$34.00	$1.79	$1.77	$1.75	$1.73	$1.70	$1.68	$1.66	$1.63	$1.61	$1.59	$1.57	$1.54	$1.52
$36.00	$1.57	**$1.54**	$1.52	$1.50	$1.48	$1.45	$1.43	$1.41	$1.38	$1.36	$1.34	$1.32	$1.29
$38.00	$1.34	$1.32	$1.29	$1.27	$1.25	$1.22	$1.20	$1.18	$1.16	$1.13	$1.11	$1.09	$1.07
$40.00	$1.11	$1.09	$1.07	$1.04	$1.02	$1.00	$0.97	$0.95	$0.93	$0.91	$0.88	$0.86	$0.84
$42.00	$0.88	$0.86	$0.84	$0.82	$0.79	$0.77	$0.75	$0.72	$0.70	$0.68	$0.66	$0.63	$0.61
$44.00	$0.66	$0.63	$0.61	$0.59	$0.56	$0.54	$0.52	$0.50	$0.47	$0.45	$0.43	$0.41	$0.38
$46.00	$0.43	$0.41	$0.38	$0.36	$0.34	$0.31	$0.29	$0.27	$0.25	$0.22	$0.20	$0.18	$0.16
$48.00	$0.20	$0.18	$0.16	$0.13	$0.11	$0.09	$0.06	$0.04	$0.02	$0.00	-$0.03	-$0.05	-$0.07
$50.00	-$0.03	-$0.05	-$0.07	-$0.09	-$0.12	-$0.14	-$0.16	-$0.19	-$0.21	-$0.23	-$0.25	-$0.28	-$0.30
$52.00	-$0.25	-$0.28	-$0.30	-$0.32	-$0.35	-$0.37	-$0.39	-$0.41	-$0.44	-$0.46	-$0.48	-$0.50	-$0.53
$54.00	-$0.48	-$0.50	-$0.53	-$0.55	-$0.57	-$0.60	-$0.62	-$0.64	-$0.66	-$0.69	-$0.71	-$0.73	-$0.75
$56.00	-$0.71	-$0.73	-$0.75	-$0.78	-$0.80	-$0.82	-$0.85	-$0.87	-$0.89	-$0.91	-$0.94	-$0.96	-$0.98
$58.00	-$0.94	-$0.96	-$0.98	-$1.01	-$1.03	-$1.05	-$1.07	-$1.10	-$1.12	-$1.14	-$1.16	-$1.19	-$1.21

White Pellets - Net Benefit in $/GJ- Sensitivity to Wood Costs

Hog Fuel Cost per Tonne (green)

Pellet Feedstock Cost per Tonne (green)	$18.00	$20.00	$22.00	$24.00	$26.00	$28.00	$30.00	$32.00	$34.00	$36.00	$38.00	$40.00	$42.00
$34.00	$1.59	$1.57	$1.55	$1.53	$1.50	$1.48	$1.46	$1.44	$1.41	$1.39	$1.37	$1.35	$1.33
$36.00	$1.37	**$1.35**	$1.33	$1.30	$1.28	$1.26	$1.24	$1.21	$1.19	$1.17	$1.15	$1.12	$1.10
$38.00	$1.15	$1.12	$1.10	$1.08	$1.06	$1.03	$1.01	$0.99	$0.97	$0.95	$0.92	$0.90	$0.88
$40.00	$0.92	$0.90	$0.88	$0.86	$0.83	$0.81	$0.79	$0.77	$0.74	$0.72	$0.70	$0.68	$0.65
$42.00	$0.70	$0.68	$0.65	$0.63	$0.61	$0.59	$0.57	$0.54	$0.52	$0.50	$0.48	$0.45	$0.43
$44.00	$0.48	$0.45	$0.43	$0.41	$0.39	$0.36	$0.34	$0.32	$0.30	$0.27	$0.25	$0.23	$0.21
$46.00	$0.25	$0.23	$0.21	$0.19	$0.16	$0.14	$0.12	$0.10	$0.07	$0.05	$0.03	$0.01	-$0.02
$48.00	$0.03	$0.01	-$0.02	-$0.04	-$0.06	-$0.08	-$0.11	-$0.13	-$0.15	-$0.17	-$0.19	-$0.22	-$0.24
$50.00	-$0.19	-$0.22	-$0.24	-$0.26	-$0.28	-$0.31	-$0.33	-$0.35	-$0.37	-$0.40	-$0.42	-$0.44	-$0.46
$52.00	-$0.42	-$0.44	-$0.46	-$0.49	-$0.51	-$0.53	-$0.55	-$0.57	-$0.60	-$0.62	-$0.64	-$0.66	-$0.69
$54.00	-$0.64	-$0.66	-$0.69	-$0.71	-$0.73	-$0.75	-$0.78	-$0.80	-$0.82	-$0.84	-$0.87	-$0.89	-$0.91
$56.00	-$0.87	-$0.89	-$0.91	-$0.93	-$0.95	-$0.98	-$1.00	-$1.02	-$1.04	-$1.07	-$1.09	-$1.11	-$1.13
$58.00	-$1.09	-$1.11	-$1.13	-$1.16	-$1.18	-$1.20	-$1.22	-$1.25	-$1.27	-$1.29	-$1.31	-$1.33	-$1.36

The tables below show the net benefit <u>relative</u> to white pellets. The cells show the difference between the net benefit of black pellets and white pellets. Positive values indicate better $/GJ values than white pellets.

The advantages of black pellets are somewhat robust to increases in the CAPEX needed to build a black pellet manufacturing plant. The analysis in the previous section uses $255/tonne/year of installed capacity (versus $210 for a white pellet plant). The lower energy density of the steam exploded pellets means that the capital cost burden per GJ is higher than for torrefied pellets. If total capex per tonne per year of installed capacity for the steam explosion plant is greater than $290 then given the assumptions in this model the net benefit is lower than for white pellets.

Sensitivity of Net Beneifit in $/GJ over White Pellets to CAPEX per Tonne per Year of Installed Capacity

CAPEX per Tonne per Year of Installed Capacity

	$240	$245	$250	$255	$260	$265	$270	$275	$280	$285	$290	$295	$300
Torrefied	$0.527	$0.502	$0.478	**$0.453**	$0.428	$0.403	$0.378	$0.353	$0.328	$0.303	$0.278	$0.253	$0.228
Steam Exploded	$0.281	$0.252	$0.224	**$0.196**	$0.168	$0.140	$0.112	$0.083	$0.055	$0.027	-$0.001	-$0.029	-$0.057

The advantage is sensitive to changes in bulk and/or energy density. As the tables below show, lower bulk and/or energy densities quickly moves the metrics from positive into the negative red zone.

Torrefied Pellets - Net Benefit in $/GJ over White Pellets at $36/tonne wood cost and $20/tonne fuel cost at 50% moisture content

GigaJoules per Metric Ton

Bulk Density in kg/m^3	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0
625	-$1.865	-$1.582	-$1.315	-$1.062	-$0.823	-$0.595	-$0.380	-$0.174	$0.021	$0.207	$0.385	$0.555	$0.718
650	-$1.819	-$1.538	-$1.272	-$1.020	-$0.782	-$0.556	-$0.341	-$0.137	$0.058	$0.243	$0.420	$0.589	$0.751
675	-$1.777	-$1.497	-$1.232	-$0.981	-$0.744	-$0.519	-$0.305	-$0.102	$0.092	$0.276	**$0.453**	$0.621	$0.782
700	-$1.738	-$1.459	-$1.195	-$0.945	-$0.709	-$0.485	-$0.272	-$0.070	$0.123	$0.307	$0.483	$0.650	$0.811
725	-$1.701	-$1.423	-$1.161	-$0.912	-$0.677	-$0.453	-$0.241	-$0.040	$0.153	$0.336	$0.510	$0.678	$0.837
750	-$1.667	-$1.390	-$1.129	-$0.881	-$0.646	-$0.424	-$0.213	-$0.012	$0.180	$0.362	$0.536	$0.703	$0.862
775	-$1.636	-$1.359	-$1.099	-$0.852	-$0.618	-$0.396	-$0.186	$0.015	$0.205	$0.387	$0.561	$0.727	$0.885
800	-$1.606	-$1.331	-$1.071	-$0.825	-$0.592	-$0.371	-$0.161	$0.039	$0.229	$0.410	$0.583	$0.749	$0.907

Steam Exploded Pellets - Net Benefit over White Pellets in $/GJ at $36/tonne wood cost and $20/tonne fuel cost at 50% moisture content

GigaJoules per Metric Ton

Bulk Density in kg/m^3	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0
625	-$1.158	-$0.895	-$0.647	-$0.411	-$0.189	$0.023	$0.224	$0.414	$0.596	$0.770	$0.935	$1.093	$1.245
650	-$1.112	-$0.851	-$0.603	-$0.369	-$0.148	$0.063	$0.263	$0.453	$0.634	$0.806	$0.971	$1.128	$1.279
675	-$1.070	-$0.809	-$0.563	-$0.330	-$0.109	$0.100	$0.299	$0.488	$0.668	$0.840	$1.004	$1.160	$1.310
700	-$1.030	-$0.771	-$0.526	-$0.294	-$0.074	$0.134	$0.332	$0.520	$0.700	$0.871	$1.034	$1.190	$1.339
725	-$0.994	-$0.735	-$0.491	-$0.260	-$0.041	$0.166	$0.363	$0.551	$0.729	$0.900	$1.062	$1.218	$1.366
750	-$0.959	-$0.702	-$0.459	-$0.229	-$0.011	**$0.196**	$0.392	$0.579	$0.757	$0.927	$1.089	$1.243	$1.391
775	-$0.927	-$0.671	-$0.428	-$0.199	$0.018	$0.224	$0.420	$0.606	$0.783	$0.952	$1.113	$1.268	$1.415
800	-$0.897	-$0.641	-$0.400	-$0.172	$0.045	$0.250	$0.445	$0.631	$0.807	$0.976	$1.137	$1.290	$1.437

This highlights the fact that a significant part of the $/GJ advantage of torrefaction or steam explosion is determined by shipping costs. The benefit comes from being able to put more energy on a ship for a given per shipload. Given the additional costs for production versus white pellets, the distance on the sensitivity tables above from positive into the negative red zone is not very far. The processes need to efficiently deliver pellets that contain high densities of energy per cubic meter.

If all of the steam needed for the steam explosion process were to be made from combusting hog fuel, we estimated that it will take about 0.141 ODT per tonne of pellets produced. In the table below that would put the steam explosion process into the red zone. We do not have data on how the by-products of that process will be used for energy. In the pulp making process "black liqueur" is produced from a similar process and that by-product is commonly used in recovery boilers. We would expect that a similar capture of that energy will be employed in steam explosion pellet production facilities.

	Sensitivity of Net Benefit over White Pellets in $/GJ to Changes in Wood Fuel needed for the Torrefaction Reactor or Steam Generation												
	Wood needed in ODT per Tonne of Pellets Produced for Steam Generation or Torrefaction												
	0.000	0.016	0.031	0.047	0.063	0.078	0.094	0.109	0.125	0.141	0.156	0.172	0.188
Torrefied	$0.453	$0.421	$0.390	$0.359	$0.328	$0.296	$0.265	$0.234	$0.203	$0.171	$0.140	$0.109	$0.078
Steam Exploded	$0.196	$0.164	$0.132	$0.100	$0.068	$0.036	$0.004	-$0.028	-$0.060	-$0.092	-$0.124	-$0.157	-0.18856

Conclusion

If the producer can deliver energy densities per cubic meter as high as or higher than shown in this model, the net benefit over white pellets can transfer to both the buyer and the producer. The buyer could pay a lower price per GJ and the seller can earn a higher profit per GJ as long as those adjustments do not take the net benefit below the project's hurdle rate for returns.

This analysis does not quantify several other potential benefits such as hydrophobicity and improved grindablity. The elimination or reduction of the need for dry storage can make the conversion costs for a coal plant lower and improve the total cost of generation with pellet fuel. Water resistance can also improve ship loading and unloading timing since white pellet loading operations have to be curtailed when it is raining or snowing. The improved grinding characteristics can lower operating costs for the power plant.

This analysis also does not look at the mill-to-port and port storage and loading costs (pre-FOB logistics costs). All of those costs, in terms of $/GJ, will be sensitive to the energy density per tonne since they are typically based on tonnes moved, stored, and loaded. It is possible that specific deals can be made based on cubic meters rather than tonnes. Since each project is quite different, we will save that modeling for specific projects.

Perhaps the larger challenge is that, as yet, the market for torrefied and steam exploded pellets barely exists. Partially that is due to the persistent failure of the technology developers over a number of years to get the mass and energy balances of the production processes in line with an economic model that works. Expectations for the development of profitable processes have been repeatedly delayed. Utility buyers are deservedly skeptical.

Furthermore, utility buyers are used to white pellets. They know that they work in their boilers and they know that they can be produced consistently and reliably. Finally, there are multiple producers of white pellets with excess capacity so if one plant has an interruption, the demands for fuel can still be fulfilled and the generators can keep spinning.

Based on this analysis, it would appear that the mass and energy balance challenge has been met by some major providers who already have a strong presence in the wood pellet sector. The other challenges will take time, patience, and persistence.

But based on the analysis presented in this white paper, the normal utility grade pellet sometime in the not too distant future may not be a white pellet. If the $/GJ cost of the low carbon sustainably produced fuel delivered to the power plant can lower the cost of generation, it will be the fuel that is used no matter what color the pellets are.

[FutureMetrics realizes that the manufacturers of equipment for torrefaction or steam explosion conversions may have different values for the key inputs in the model that we have developed. We welcome feedback and will comment on that feedback in a follow-up paper. However we will only accept data from sources that have operational small commercial scale systems producing torrefied or steam exploded pellets just as they would in a fully scaled commercial operation. We will not use data from laboratory/bench or even pilot scale projects. We are particularly interested in mass and energy balances and capital costs for a project in $/tonne/year of installed capacity.]