FutureMetrics LLC
8 Airport Road
Bethel, ME 04217, USA

Debunking two so-called "facts" about Wood Pellets

By William Strauss, PhD, President, FutureMetrics, July 6, 2015

There are two highly inaccurate statements that are often made about the use of wood pellets as a substitute for coal in power generation. (1) The CO_2 released from the combustion of wood pellets is greater than the CO_2 released from the combustion of coal; (2) Using wood pellets for heat or power creates a carbon debt that takes decades to repay.

The Manomet study[1] released in June, 2010 codified both of those so-called facts about using wood for fuel. Since then both the "pellets are worse than coal" and the "carbon debt" arguments have become ingrained in the anti-biomass literature.

In this white paper we will show why those statements, often presented as facts, are inaccurate.

Do pellets release more CO_2 in combustion than coal? Coal started its life a very long time ago as biomass. And, it turns out, on a dry basis, coal and wood yield similar results in terms of the CO_2 produced (in kilograms of CO_2 per unit of potential energy)[2]. Of course wood does not have zero moisture content (MC). But neither does coal. The typical moisture contents by weight of coal are anthracite 3% - 16%, bituminous and sub-bituminous 8% - 20%, and lignite 39% or more.

Carbon contents also vary. Hardwood to softwood ranges from 48.5% to 51.5%. Coal varies widely. Lignite is about 40%, sub-bituminous is about 67%, bituminous is about 82%, and anthracite is about 95%.

It is the water in the solid fuel that causes its CO_2 emissions to increase over the dry weight basis. The underlying process that drives this is "the enthalpy of vaporization". In simple terms, it takes energy to evaporate the water in the wood or coal and convert it to vapor (steam). All of that energy is sent into the atmosphere in the form of water vapor and is lost. So to get a million BTUs of useful energy from the solid fuel, a larger mass of wood or coal is necessary to compensate for the losses from vaporizing the water. More wood or coal per unit of energy means more CO_2 per unit of energy.

The analysis of carbon emissions from wood and coal will vary depending on the grade and MC of the coal. At 45% MC for wood, which is the level used by the Manomet study (page 103) and which is a common MC for green wood chips, and at 15% MC for sub-bituminous coal, the combustion of wood for power yields about 34% more CO_2 per unit of useful energy then power generated from sub-bituminous coal[3].

But green wood chips are not suitable for use in almost all coal power plants. Most of the power generated from coal in the US is from bituminous and sub-bituminous coal (96%) and most is used in

[1] https://www.manomet.org/sites/default/files/publications_and_tools/Manomet_Biomass_Report_Full_June2010.pdf
[2] Wood ranges from 116 to 123 kg/MMBTU for hardwoods to softwoods and coal ranges from 115 to 125 kg/MMBTU from sub-bituminous to lignite. Both are values assume no moisture content.
[3] The tables at the end of this paper contain all of the calculations.

power plants that pulverize the coal and send it to burners on the boiler sidewalls. Wood pellets pulverize easily and millions of tons per year are used as a substitute for coal in pulverized coal power plants around the world.

The correct solid wood fuel for comparison with coal is wood pellets not green wood chips. Wood pellets will be the fuel that will be used in US coal plants to lower carbon emissions.

Pulverized solid fuel in a power plant boiler

At lower moisture contents the CO_2 released by combustion is less because more of the energy is available to do useful work. Wood pellets at 6% MC results in less CO_2 emissions from combustion than all grades of coal under otherwise equal circumstances[4].

Ratio of CO_2 Emitted from Wood versus Coal		
Coal MC	Wood MC	**Wood vs Coal**
15%	6%	**-21.58%**
15%	45%	**34.03%**
Positive means wood emits higher CO_2		

Wood pellets release less CO_2 per unit of useful energy than coal. Furthermore, even for green wood chips that release more CO_2 in combustion than coal, there is no carbon debt.

Why there is no carbon debt. If the wood that is used for pellet production comes from working forests in which the aggregated stock of wood held in the forests is not shrinking then the carbon stock

[4] The table is based on sub-bituminous. The inputs to the calculation are as follows: higher heating values of wood pellets and coal at 18.5 and 21.5 MJ/kg; carbon content of wood pellets and coal at 50% and 67% respectively; power plant efficiency at 37%. Wood pellets are also lower in CO_2 emissions from combustion than lignite, bituminous, and anthracite.

in those forests is not being depleted. If that constraint is met, then every ton of carbon emitted from the combustion of chips or pellets is absorbed contemporaneously.

This dynamic is illustrated in the chart on the next page. In this example, the working forest is harvested annually and after each harvest the plot that was harvested is replanted. In this stylized example the tree farmer harvests one plot per year, which is the forty year old mature plot. The carbon sequestration rate is 10,000 tons the first year. There are 40 separate plots at 40 stages of growth from seedling to mature, and each plot sequesters carbon every year at a declining rate as the trees mature. The entire forest sequesters 152,640 tons per year every year. The accumulated carbon in the mature 40 year old stand exactly equals the carbon accumulated every year by all the younger stands. So although 152,640 tons of carbon are released by the fiber in the 40 year old plot when used as pellets for fuel, 152,640 tons of carbon are sequestered in the same year by each of the other plots including the replanted plot on the site of the most recent harvest.

Demand for forest product are continuous. Harvesting, replanting, and regrowth happens every day; not once per year. So the carbon released by the continuous use of pellets consumed daily for power generation is sequestered immediately by the continuous regrowth that occurs in balance with the harvest. Working forests can renew forever if they are managed properly. Some of each harvest, the larger diameter straight logs, will be used to produce lumber. So the amount of carbon released by pellet combustion is less than the amount sequestered.

The anti-biomass literature is wrong on wood pellets. The combustion of wood pellets releases less CO_2 than that the combustion of coal; and as long as there are sustainability criteria that make sure that the aggregate stock of carbon in the working forests is never lowered, there is no carbon debt.

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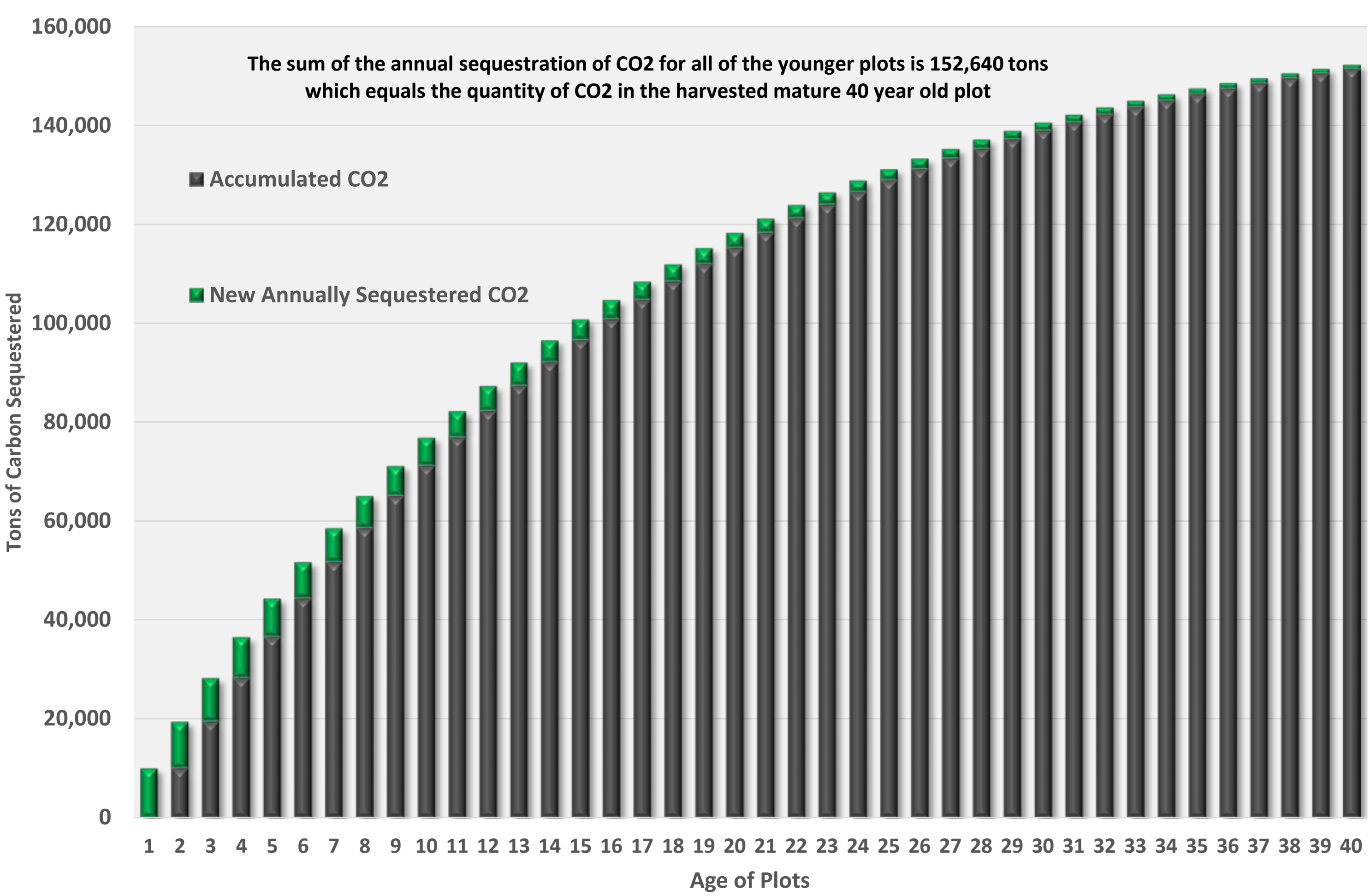
Diagram of Forest Landscape with 40 Stages of Growth and Assumed Sequestration Rate of 10,000 Tons of CO2 the First Year



Analysis by FutureMetrics

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WOOD

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
MCx	ratio MCx wood to MC0 wood	DME (dry mass eq.) (kg MCx/kgMC0)	GHV (MJ/kg)	wood (kg/tonne)	water (kg/tonne)	carbon (kg/tonne)	water to evap. (kg/DME)	energy lost (MJ/DME)	energy lost (MMBtu/DME)	NHV (MJ/kg)	Efficiency=37% Usable net HV (MMBtu/DME)	DME (kg) of MCx wood per MMBtu of Usable HV	Corresponding Carbon content (kg/MMBtu)	CO_2 emissons (kg/MMBtu)
0	1.000	1000.000	18.50	1000	0	500	0.00	0.0	0.000	6.85	6.49	154.11	77.05	282.53
6	1.064	1063.830	17.39	940	60	470	63.83	144.1	0.137	6.05	6.10	174.41	81.97	300.56
8	1.087	1086.957	17.02	920	80	460	86.96	196.3	0.186	5.79	5.97	182.07	83.75	307.09
10	1.111	1111.111	16.65	900	100	450	111.11	250.8	0.238	5.54	5.84	190.25	85.61	313.92
15	1.176	1176.471	15.73	850	150	425	176.47	398.3	0.378	4.95	5.52	213.29	90.65	332.38
20	1.250	1250.000	14.80	800	200	400	250.00	564.3	0.535	4.38	5.19	240.79	96.32	353.16
25	1.333	1333.333	13.88	750	250	375	333.33	752.3	0.713	3.85	4.87	273.97	102.74	376.70
30	1.429	1428.571	12.95	700	300	350	428.57	967.3	0.917	3.35	4.54	314.50	110.08	403.61
35	1.538	1538.462	12.03	650	350	325	538.46	1215.3	1.152	2.89	4.22	364.75	118.54	434.66
40	1.667	1666.667	11.10	600	400	300	666.67	1504.7	1.426	2.46	3.89	428.07	128.42	470.88
45	1.818	1818.182	10.18	550	450	275	818.18	1846.6	1.751	2.07	3.57	509.44	140.10	513.69
50	2.000	2000.000	9.25	500	500	250	1000.00	2257.0	2.140	1.71	3.24	616.42	154.11	565.05

COAL - Sub-Bituminous

MCx	ratio MCx coal to MC0 coal	DME (dry mass eq.) (kg MCx/kgMC0)	GHV (MJ/kg)	coal (kg/tonne)	water (kg/tonne)	carbon (kg/tonne)	water to evap. (kg/DME)	energy lost (MJ/DME)	energy lost (MMBtu/DME)	NHV (MJ/kg)	Efficiency=37% Usable net HV (MMBtu/DME)	DME (kg) of MCx coal per MMBtu of Usable HV	Corresponding C content (kg/MMBtu)	CO_2 emissions (kg/MMBtu)
0	1.000	1000.000	21.50	1000	0	670	0.00	0.0	0.000	7.96	7.54	132.60	88.84	325.76
6	1.064	1063.830	20.21	940	60	629.8	63.83	144.1	0.137	7.03	7.09	150.07	94.51	346.55
8	1.087	1086.957	19.78	920	80	616.4	86.96	196.3	0.186	6.73	6.94	156.67	96.57	354.09
10	1.111	1111.111	19.35	900	100	603	111.11	250.8	0.238	6.44	6.79	163.71	98.72	361.96
15	1.176	1176.471	18.28	850	150	569.5	176.47	398.3	0.378	5.75	6.41	183.53	104.52	383.25
20	1.250	1250.000	17.20	800	200	536	250.00	564.3	0.535	5.09	6.03	207.19	111.05	407.20

Col C	MC is percent moisture content, wet basis. X corresponds to the stated MC
Col D	ratio MCX wood/coal to MC0 wood/coal is the ratio of the mass of wet material at MCx required to get 1 unit wood/coal at MC0
Col E	DME (dry mass equivalent) is the mass of wood/coal (kg) at MCx required to yield 1000 kg of wood/coal at MC0
Col F	GHV (MJ/kg) is the Gross Heating Value of wood/coal. GHV = high heating value (HHV) * (1-MC/100)
Col G	wood/coal (kg/tonne) is the mass of bone dry wood/coal in 1 tonne of wood/coal at MCx
Col H	water (kg/tonne) is the mass of water in 1 tonne of wood/coal at MCx
Col I	carbon (kg/tonne) is the mass of carbon in 1 tonne of wood/coal at MCx. Assumes C=50% by wt.
Col J	water to evaporate (kg/DME) is the mass of water to evaporate per DME
Col K	energy lost (MJ/DME) is the heat lost to the vaporization of the water in the wood/coal; 2257 kJ/kg
Col L	energy lost (MMBtu/DME) is the heat lost to the vaporization of the water in the wood/coal; (MJ * 948 / 1000000 = MMBtu)
Col M	NHV (Net Heating Value in MMBtu) is equal to the Gross Heat Value at MCx * Boiler Efficiency
Col N	Usable net heat value (HV) = NHV * DME *948/1000000
Col O	DME (kg) of MCx wood/coal per MMBtu Usable HV = DME / Usable HV
Col P	corresponding C content = (value from Col O * carbon content from Col I) / 1000
Col Q	CO_2 generation = value from Col Q * 44/12 (ratio of molecular weight CO_2 (44) to the molecular weight Carbon (12) => 44 / 12)