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Biomass Carbon Capture and Sequestration

When used with sustainably sourced biomass-based fuels,

significant carbon negative outcomes are achievable.

By William Strauss, PhD
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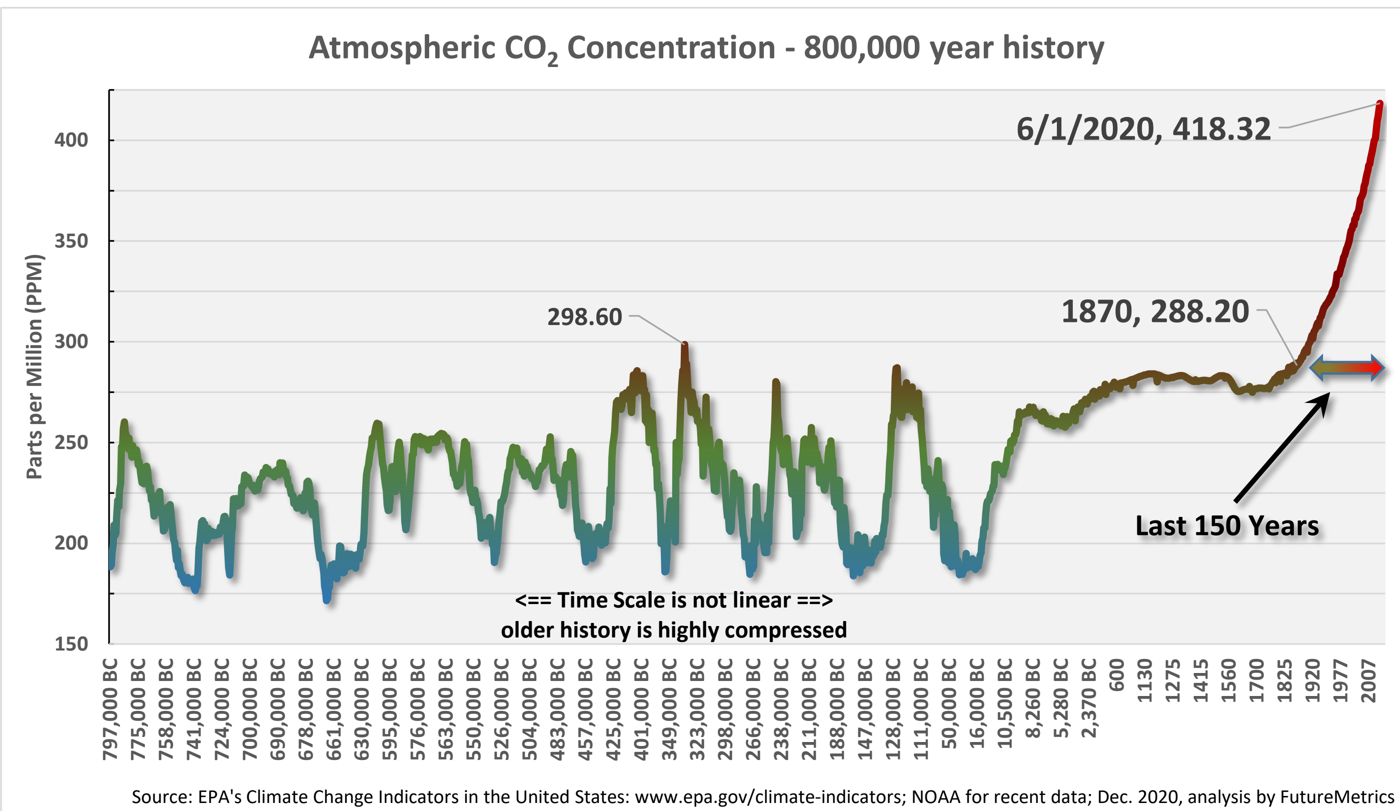
The transition from carbon-based energy to renewable energy will take decades[1]. In the meantime, the major forcing component of climate change, carbon dioxide (CO_2), will continue to be emitted. Over the past century, atmospheric concentrations of CO_2 have accelerated[2]. Fossil fuels that are from the soaked-up carbon from over hundreds of millions of years during their formation are releasing all that carbon in very short order.



[1] See the recent FutureMetrics white paper "A Climate Strategy for the Biden Administration" for a discussion of the challenges of deploying energy storage solutions to compliment increasing reliance on wind and solar power.
[2] See the interactive chart of current and historical greenhouse gas concentrations on the FutureMetrics homepage.

The "greenhouse effect" that causes the planet to warm and the acidification of the oceans[3] are consequences of this rapid injection of geologic carbon into the earth's systems. Both of those consequences are leading to disastrous outcomes for civilization.

To alter that trajectory, a future that relies on non-carbon emitting energy is necessary. Countries and companies in many jurisdictions are pledging to reach goals that will lower carbon emissions dramatically over the coming decades.

However, it is becoming clear that more aggressive strategies are needed to slow and eventually stop carbon emissions and reduce atmospheric CO_2 concentrations. So the goals for those countries and companies need to be broadened to include ways to prevent CO_2 from entering the atmosphere. Carbon capture and sequestration (CCS) is a broad concept that describes this strategy.

Research and development in CCS is accelerating rapidly in many jurisdictions[4]. CCS will be an essential tool in the decarbonization of the power generation sector. As the technology is developed and deployed, the cost per tonne of CO_2 avoided will fall. The cost per tonne of CO_2 removed or avoided has to be balanced against the cost of carbon dioxide pollution. In the model/dashboard discussed below in this white paper, the user can adjust the total cost of CCS (capture, transport, and sequestration).

The best that CCS can do at a fossil fueled power station (natural gas, coal, or other fossil fuels), if 100% efficient in CO_2 removal, is net zero carbon emissions from combustion[5].

But there is way to get to negative net emissions: Bioenergy (or biomass) carbon capture and sequestration (BCCS or sometimes BECCS). As many FutureMetrics papers have explained, if biomass-based fuels such as wood pellets are sourced sustainably, they are carbon neutral in combustion. Thus, a power station that replaces coal with refined biomass-based fuel[6] and has CCS will be net carbon negative.

FutureMetrics has produced a dashboard that calculates the negative CO_2 emissions (in kg/MWh) and the estimated cost per avoided tonne of CO_2 when using BCCS. The dashboard calculates the cost per avoided tonne in two ways: (1) based on the change in CO_2 emission from a power plant that changes from coal to wood pellets. That includes the negative emissions from using wood pellets and BCCS and the avoided emissions from eliminating coal. And (2) based on just the negative emissions from using wood pellets and BCCS. All scenarios include the supply chain CO_2 emissions which do not contribute to CCS.

The user can choose one of several types of coal and can set the critical characteristics of the types of coal (energy density, moisture content, and carbon content) and the pellet fuel. Delivered costs of the fuels to

[3] See https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification
[4] See link for details https://en.wikipedia.org/wiki/Carbon_capture_and_storage
[5] All fuels currently require that some fossil fuels are used in their refinement and transportation.
[6] With modest modification costs, the power station is not derated both in terms of instantaneous output and uptime.

the power plants and the efficiency of the power plant can be selected by the user. The cost of the CCS component can also be adjusted.

The dashboard only considers the fuel costs in the analysis. That is, the capital cost of modifying the power station is not included. The purpose of the dashboard is to show in simple terms the significant benefit of BCCS.

The model behind the dashboard makes it clear that the lower quality coals such as lignite offer the most net negative CO_2 benefit from the change from coal to wood pellets. The screenshot on the next page shows the lignite scenario with the default settings for all other inputs.

If the avoided CO_2 emissions from the converted lignite fueled power plant are used in the calculation of the cost per avoided tonne, even with the cost of the CCS component set to $75/MWh, the estimated cost is a very modest $24.75 per tonne. That is, under the assumption that the avoided emissions from the converted lignite fueled power station are part of the net CO_2 reduction, a cost for emitting carbon of only $25 per tonne of CO_2 would be sufficient to motivate the change. The net change in CO2 emissions is negative 2,542 kg/MWh. If the cost per tonne of CO_2 sequestered only considers the use of pellet fuel in the converted lignite power station, the cost per tonne with all other assumptions being the same is estimated to be about $66.50 and the net rate of sequestration (i.e., negative emissions) is 908 kg/MWh.

Obviously lowering the assumed cost per MWh of the CCS component lowers those costs. Lower CCS costs would appear to be highly likely[7].

The dashboard is free to use and can found on the FutureMetrics homepage. A direct link to the dashboard is HERE.

To counter the carbon crisis, we have to have a meaningfully defined off-ramp to a decarbonized future. Every decarbonization strategy should include CCS. Carbon zero is good, carbon negative is better.

The only pathway to significant negative CO_2 emissions in the power generation sector is biomass carbon capture and sequestration.

[7] See THIS reference suggests that costs are already lower than the dashboard's default setting of $75/MHh.

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Coal Inputs

- (●) Lignite (brown coal)
- ( ) Peat
- ( ) Sub-Bituminous coal
- ( ) Semi anthracite
- ( ) Bituminous coal
- ( ) Anthracite coal

Set the Higher Heating Value of the Coal

Lignite (brown coal) Higher Heating Value = 15 MJ/kg

Set the Moisture Content of the Coal

Lignite (brown coal) Moisture Content = 45.0%

Set the Carbon Content of the Coal

Lignite (brown coal) Carbon Content = 65.0%

Coal Delivered Cost = $75.00 per Tonne

Coal Cost per MWh = $46.15

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FutureMetrics Website

Pellet Fuel Inputs

Pellet Energy Content = 17.5 GJ/Tonne

Pellet Moisture Content = 6.0%

Pellet Carbon Content on Dry Basis= 50.0%

Supply Chain CO_2 Footprint as a Percent of Total CO_2 = 12.0%

Pellet Fuel Delivered Cost = $190.00 per Tonne

Pellet Fuel Cost per MWh = $100.22

Net Fuel Cost Increase with Pellets = $54.07 per MWh

Total Incremental Cost over Straight Coal = $129.07 = per MWh

Net Cost per Tonne of Avoided CO_2

Biomass Carbon Capture and Sequestration (BCCS) Dashboard by FutureMetrics

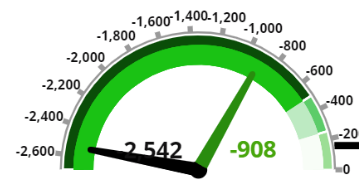
Power Plant Efficiency = 39.0%

Lignite (brown coal) CO_2 Emissions = 2,666 kg/MWh

Pellets CO_2 Emissions = 1,032 kg/MWh

Pellet Supply Chain CO_2 Footprint= 124 kg/MWh

Net Change in CO_2 Emissions by Replacing Coal with Pellets and using BCCS (in kg/MWh)



Black = Net Change from Coal

Green = From Pellets Only

Replacing coal with pellets removes 2666 kg/MWh of coal CO_2 emissions. Sustainably sourced pellets are carbon neutral in combustion, but the pellet supply chain adds 124 kg/MWh of CO_2 to the net emissions.

Capturing and sequestering the CO_2 yields a net change in the emssions rate of NEGATIVE 2542 kg of CO_2 per MWh.

The net CO_2 emssions rate from using pellet fuel with BCCS is NEGATIVE 908 kg of CO_2 per MWh.

Total Cost of BCCS = $75.00 per MWh

Includes the cost of carbon capture, transport, and sequestration

Choose How to Calculate the Cost per Avoided Tonne of CO_2

(●) Net from Replacing Coal ( ) Net from Just the Pellets