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The Lowest Cost Solution for Maximum Decarbonization of the Power Sector while Maintaining Grid Reliability

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The economics of power generation combined with the need to keep the grid energized under all scenarios can provide guidance for determining the least costly way to avoid carbon emissions while maintaining grid reliability. The metric that should inform decision making as to how to best lower carbon emissions is based on the total investment and operating cost per avoided ton of CO_2.

This white paper will discuss this metric and will compare the analytics of two scenarios that provide on-demand dispatchable power: (1) Retire coal power plants and replace them with new combined cycle natural gas generating stations, and (2) Modify existing pulverized coal power plants to use renewable industrial wood pellets as a substitute for coal. This paper shows that when comparing the two scenarios, and when factoring in the reduction in CO_2 emissions from each technological solution, the solution that provides significantly higher CO_2 reduction at a lower net monetary cost per avoided ton is by repurposing existing pulverized coal power plants to run on industrial wood pellets.

Why Baseload and On-demand Peaking Generation is Necessary

There are essentially two broad categories of utility scale power generation: (1) Baseload and on-demand (peaking). These sources of power are typically from thermal generation[1], or from non-thermal generation using hydro power; and (2) intermittent and variable power produced by wind and solar farms. Peaking generation is used when baseload and intermittent sources need topping up to keep the grid energized either due to low or zero output from wind and solar, or due to very high demand.

As governments legislate policy with the goal of reducing carbon emissions, lower carbon emitting generation is required. Wind and solar power provide a zero-carbon emitting solution. But wind and solar provide variable power output; and sometimes zero power output. So, if the power grid is to remain reliable at all times, it needs sources of generation that can be depended upon at any time to provide, in worst case scenarios, nearly 100% of the demand.

That source of reliable power has traditionally been via coal, natural gas, nuclear, and hydro. In most jurisdictions, utility scale hydro has been fully exploited. Even if there is hydro potential, it takes many years to implement. Nuclear power has attraction as a low carbon generation source but is very costly

[1] Thermal generation requires heating a boiler to make high pressure and high temperature steam to spin turbines and generators. The heat is produced from the combustion of coal, natural gas, and, more recently, wood pellets, or from nuclear reactions.

to build, also takes many years to deploy, and comes with other issues such as what to do with spent fuel and how to shield the plants from potential attacks.

That leaves coal and natural gas fueled power plants because, as noted above, some form of on-demand generation is needed to keep the grid fully powered when intermittent sources are not contributing sufficient power. Because of low natural gas prices and natural gas's lower carbon emissions versus coal, many utilities are choosing to build new high efficiency natural gas combined cycle plants. This is a relatively easy-to-deploy pathway to lowering carbon emissions while keeping reliable baseload or peaking power on the system.

But as this white paper will show, when measured by the present value of the total capital and operating costs per avoided ton of CO_2, building new natural gas power plants is not the least costly way to mitigate carbon emissions while providing dispatchable generation.

Building New Natural Gas Plants or Converting Existing Pulverized Coal Plants to Use Wood Pellets?

Policymakers and utilities often see natural gas generation as a compromise between coal and the need for reliable on-demand low-carbon power. While natural gas (NG) is a fossil fuel, it offers lower CO_2 emissions per MWh generated than coal[2].

NG is perceived as a favorable solution since the cost to build a new efficient combined cycle power plant is relatively low compared to nuclear and hydro, time to build is relatively short, and the fuel costs are almost at historic lows.

But if CO_2 reduction is the primary goal of policy and therefore of the utility, the correct decision metric is not simply the capital cost for the plant and operating costs to make power. The correct decision metric should include a recognition of the impact that the project will have on CO_2 emissions. The decision metric used in this analysis shows the cost of CO_2 mitigation as a function of the capital investment and operating costs over time. The net present value (NPV) of the CAPEX and OPEX over a reasonable time span at an appropriate discount rate captures the value in current dollars of the total cost of the project. Comparing that number with the avoided CO_2 emissions realized from using a lower carbon emitting fuel yields a decision metric based on both financial and environmental concerns. Calculating the lowest cost per avoided ton of CO_2 combines good environmental policy with good business.

The alternative to building a new natural gas combined cycle (NGCC) plant is to leverage existing power plants that are designed to efficiently combust pulverized coal (PC). Modern PC power plants can, with

[2] How much NG lowers CO_2 emissions versus coal depends on the type of coal it is being compared to and the efficiencies of the coal and natural gas power plants.

easy to deploy modifications and additions to the equipment, substitute industrial wood pellets for coal[3]. The capital costs for the modification are significantly lower than the capital cost for a new NGCC plant (on average about 40% the capital cost of a new NGCC plant) and the construction time for modifications is less than two years. The operating costs however are higher. Pellet fuel is costlier than NG.

But the carbon reduction from a fully converted pulverized coal power plant using wood pellet fuel versus coal is significantly better than that from a new NGCC plant versus coal. The reduction in CO_2 emissions from NGCC versus modern coal power plant is about 46%[4]. The reduction in CO_2 emissions from a modern pulverized coal plant converted to use renewable wood pellets is about 90%[5].

The analysis that follows uses the default settings that are used in a new FutureMetrics dashboard. The dashboard allows the user to change many of the critical assumptions that determine the results of the analysis. The dashboard can be opened by going to the FutureMetrics website and scrolling down the home page to the dashboard section or directly from this paper by clicking HERE.

Using typical costs for building a new 600 MW NGCC plant and current costs for the NG fuel, the net present value of the initial capital cost, fixed costs including labor, and the fuel costs over ten years, discounted at 6%, is about $1.83 billion. Using the same analysis for a coal plant conversion to use wood pellets, which has a lower initial capital cost but higher fuel costs, the NPV is about $3.19 billion. Clearly the present value of the total costs is higher for the pellet conversion scenario.

However, the if policy goal is to reduce carbon emissions, the lowest cost per ton of CO_2 avoided should be the market-based metric for a comparison.

Taking the avoided tons of carbon emissions for both scenarios and calculating the net present value of the cost of avoided carbon emissions over ten years yields the results in the table below[6]. Note that this analysis only looks at costs. The revenues from power sales are assumed to be the same. More on this below.

[3] See several white papers at the FutureMetrics website on this topic.
[4] Based on EIA data. https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11
[5] See the FutureMetrics dashboard for carbon emissions from using pellets in power plants HERE. Opening this and the other dashboards requires Adobe Flash and a compatible web browser. Also, see FutureMetrics white papers on carbon accounting of wood pellet used in power generation at the FutureMetrics website.
[6] As noted above, the assumptions that produced the results are the default settings in a new FutureMetrics dashboard. The reader is encouraged to open the dashboard and experiment with changing assumptions. Take particular note of the impact of changes in capacity factor. For power stations with lower capacity factors, such as peaking plants, the results are significantly more favorable for the pellet conversion scenario.

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Plant size = 600 MW's - Capacity factor = 75%			
	Coal to Pellets Conversion	New Combined Cycle NG Plant	Coal Generation
Tons of CO2 Produced over 10 Years	4,080,969	23,287,753	40,067,692
Tons of CO2 Avoided over 10 Years Compared to Coal	35,986,724	16,779,939	0
Percent Reduction vs. Coal	89.8%	45.8%	0%
NPV of Total Costs at a 6.0% Discount Rate over 10 Years	($3,194,750,524)	($1,833,659,375)	
NPV of the Cost per Avoided Ton of CO2	**$89**	**$109**	

Under the assumptions in the model, the conversion of an existing coal plant from using coal to using low carbon renewable industrial wood pellets is the least costly pathway for achieving the goal of lowering carbon emissions. The conversion scenario results in a 23.1% lower cost per ton of CO_2 not placed into the atmosphere.

As has been proven by many coal-to-pellet conversions of power stations globally, there is no de-rating of the power station if the modifications that are included in the capital cost assumptions are implemented. Efficient coal power plants converted to use pellet fuel have the same efficiency and reliability after making modifications to the fuel handling and feed systems as they did when combusting coal.

The operating costs, due primarily to the higher cost per unit of energy for wood pellet fuel, are higher for the converted plants. That is why government policy with respect to the revenues of the generating entity are essential.

Policy Needs to Support the Least Costly Pathway to Decarbonizing the On-Demand Generation Mix

Decarbonization policies are necessary to address climate change[7]. The best strategic plans should be broader than only including support for wind and solar generation. On-demand baseload and peaking plants must exist to compliment the variability and potential very low output of wind and solar generators. The current trend of retiring coal fired power plants and building new high efficiency natural gas fired plants is rational if minimizing operating costs is the only decision metric.

However, if policymakers' primary goal is to lower carbon emissions, it makes better economic and environment sense to choose the pathway with the lowest total cost per avoided ton of CO_2. That suggests that complimenting any decarbonization policy there needs to be support for converted PC power plants that will have higher fuel costs. If there is no policy support to compensate the utility for maximizing CO_2 reduction via the lowest net cost pathway, NGCC will be favored. As a result, the aggregate quantity of CO_2 emitted will be significantly higher and the total net cost per avoided ton will

[7] See a recent FutureMetrics white paper on this topic HERE.

also be higher. Those outcomes are worse for the environment and worse economically than the conversion alternative.

Converting coal plants to pellets cannot replace all of the on-demand generation fleet. The quantity of industrial wood pellets that could be produced is limited by the sustainability requirements that govern the sourcing of the pellet fuel feedstock. The limits are defined by how much feedstock can be sourced without depleting the carbon stock held by the continuously growing/renewing biomass resource. But as long as the extraction rates do not exceed the growth rates, the carbon benefits can be realized because there is no net new carbon added to the atmosphere from the combustion of the fuel produced from sustainable sources. Carbohydrate based fuels that are derived from continuously renewing biomass sources are carbon neutral in combustion.[8] Hydrocarbon based fuels, which are mined and extracted from the earth, always increase the concentration of CO_2 in the atmosphere.

Conclusion

Within the boundaries of sustainability, there is the potential for many power plants to consider conversion from coal to pellets. But the policy mechanisms must compensate the generators for the higher cost of the fuel. Carbon reduction policy requires complementary policy mechanisms to guide the markets toward the optimal solution in terms of the cost per avoided ton[9].

Regulations aimed at minimizing environmental impacts from any pollutant typically result in a higher cost of production: the external costs of pollution are internalized by the producers because of policy requirements. In any industrial sector, if left unregulated, producers default to the lowest production costs regardless of environmental impacts. That is why policy regulates emissions. The well-being of society, now and in the future, requires intervention.

Carbon emissions reduction requires intervention via policy and regulation. Policymakers need to set goals and then to put in place the mechanisms that support the optimal solutions. Without accounting for the cost per avoided ton of carbon pollution, the lowest cost strategy for the power sector for dispatchable power will default to new high efficiency natural gas fired power plants. That solution should be part of the portfolio; but not the only choice.

As this paper has shown, when comparing NGCC and coal-to-pellet conversion, and when factoring in the reduction in CO_2 emissions from each technological solution, the solution that provides significantly higher CO_2 reduction at a lower net monetary cost to society per ton avoided is by repurposing existing PC power plants to run on industrial wood pellets.

[8] See a recent FutureMetrics white paper on this topic HERE.
[9] Footnote 3 has a link to a dashboard that shows the incremental cost for switching. Move the co-firing slider over to 100% pellets to see the cost per MWh for a full conversion. It is the lowest cost on-demand renewable power solution other than hydro.