Quantified Benefits of Co-firing Biomass with Coal for Economic and Pollutant Relief

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Abstract

With the concentration of carbon dioxide and global temperatures rising together, it is well documented that greenhouse gases, most infamously carbon dioxide, has been an anthropogenic source of rising temperatures known as, global warming. The main source of GHG's is combustion of fossil fuels, such as coal, in order to generate power. With a significant portion of US power generation dependent on coal, mostly from electricity generation, replacing all coal in power plants is not feasible in the short run. A faster, more reasonable goal is to fire biomass and coal together, a process known as co-firing, which can be done in different percentages of increasing biomass. To estimate the outcome of co-firing, several factors needed to be addressed: energy input and effect on the environment. Percentage of co-firing was divided into increments of 5% increases, starting with 10% and ending with 30%, and change of energy efficiency was calculated. The effects on three different types of emissions: carbon dioxide, sulfur oxide, and nitrous oxide were quantified at a 20% co-fire rate. Since the extent of emission reduction differs in biomass, we used wood as an example, leading to reductions in all emissions. The reduction of pollution and energy input change was quantified regionally and compared to plants firing coal alone. Less NOx and SOx emissions will reduce the frequency of respiratory health problems and reduce acid rain, and biomass combustion will result in less atmospheric CO2, with more CO2 absorbed into carbon reservoirs. These results show great social benefits, as well as the feasibility of co-firing biomass with coal in power generation.

Background

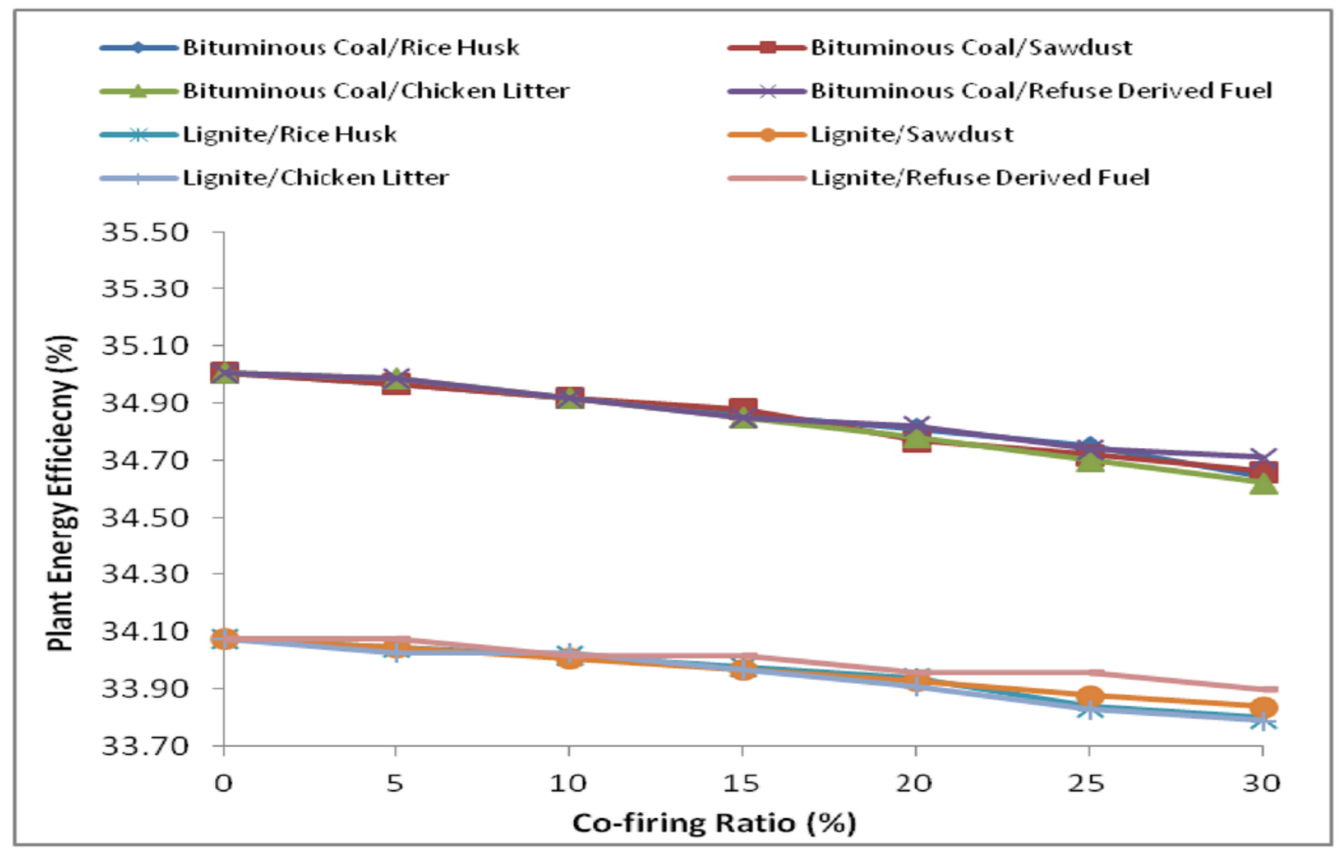
One tactic that requires less change in the energy sector infrastructure is co-firing biomass with coal to produce less pollutants such as carbon dioxide, sulfur oxides, and nitrous oxides. Co-firing, as the name suggests, requires energy use to produce power from coal, but with a ratio of biomass as well. Since biomass generally have less nitrogen, sulfur, and carbon, they always guarantee less emissions, and therefore a social benefit regarding cost and health. Though many acknowledge the fact that co-firing biomass with carbon is a tactic with a huge potential to reduce pollution quantities, the national energy sector has made slow progress with co-firing due to the fact that coal is a plentiful source of efficient fuel. Coal, however, has many social costs that come from the high amount of pollutants emitted from being used that not only hurt the environment, but people as well.

Methods and Materials

Change of Energy Efficiency

(%) Cofire	5	10	15	20	25	30
(%) Efficiency Decrease	.062	.124	.186	.248	.31	.37

- With coal decreasing, biomass increased to keep total electric generation constant:
- Coal decreased from 0-30%, co-firing with chicken litter, refuse derived fuel, rice husk, and sawdust. (2)
- Average decrease of energy efficiency from 0-30% co-firing= .37%



$$New\ Plant\ efficiency = \frac{Net\ Generation}{(Efficiency\ of\ coal) - (Efficiency\ of\ coal * \%\ efficiency\ decrease)}$$

Cost of Replacing Coal With Biomass

- The cost of using coal is 95.10$/MWh input.
- The cost of using biomass is 100.50$/MWh input. (6)

Calculating the cost per MWh:

1.Cost of coal at 20% Co-firing rate=(MWh Energy Input)(95.10$) (.8)

2.Cost of Biomass at 20% Co-firing rate=(MWh Energy Input) (100.50$) (.2)

3.Total cost at 20% co-firing = A+B

- **All coal plants** in the North Eastern region:
  - Cost of firing only coal=16,425,092,565 $
  - Total cost of co-firing at 20%=16,644,713,643 $
  - Total Difference=219,621,079 $
- **All coal plants** in the PJM region.
  - Cost of firing only coal=153,550,678,768 $
  - Total cost of co-firing at 20%=155,672,350,564 $
  - Total Difference= 2,121,671,796 $

Difference of Pollution Quantities

Lb of pollution/MM btu of Energy input	Coal (Bituminous)	Biomass (Wood)
CO2 (3)	205	213
SOx (1)	.89	.025
NOx (1)	.51	.22

Table 1. Pounds of pollutants emitted by bituminous coal and wood biomass. Biomass have extreme variations of emissions, so we will use wood as an example. Pollution is measured in lbs/MMbtu of energy output.

Using these numbers, we quantified the pollutant difference between plants firing 100% coal, versus a situation with 20% coal reduction.

Pollutant Costs: CO_2, NO_x, SO_x

- The cost of CO2 are 37$ per metric ton (5)
- The social costs of NOx and SOx are 67,000$ and 40,000$ per metric ton, respectively. (4)
- These three costs are measured in terms of damage costs per ton of pollution.

Pollutant Cost Savings

A) Total cost of Pollutants at 100% Coal = (NOx Cost+CO2 Cost+SOx Cost)$_{100\%\ coal}$

B) Total cost of Pollutants at 20% co-fire rate = (NOx Cost+CO2 Cost+SOx Cost)$_{20\%\ cofire}$

- **Total Amount ($) Saved from Pollutant Reduction = A – B**

Results

Figures 1 & 2 below both show how much energy input increases as coal reduction in co-firing increases from 0% to 30%. Notice that the energy input necessary for increase is small, almost shown as a flat line. This signifies that although energy efficiency decreases, it is only very marginal.

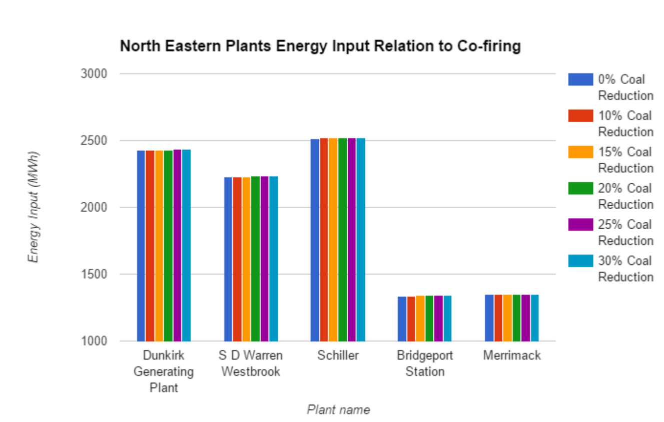


Figure 1. Northeastern power plants: Dunkirk, Warren, Schiller, Bridgeport, and Merrimack show that increased biomass percentages consistently lead to very slight increases of energy, necessary to produce the same amount of power.

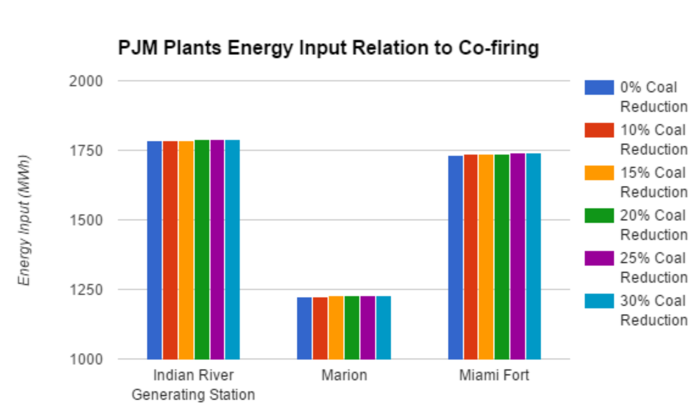


Figure 2. PJM plants: Indian River, Marion, and Mimi Fort show the same trend of increased energy input necessary.

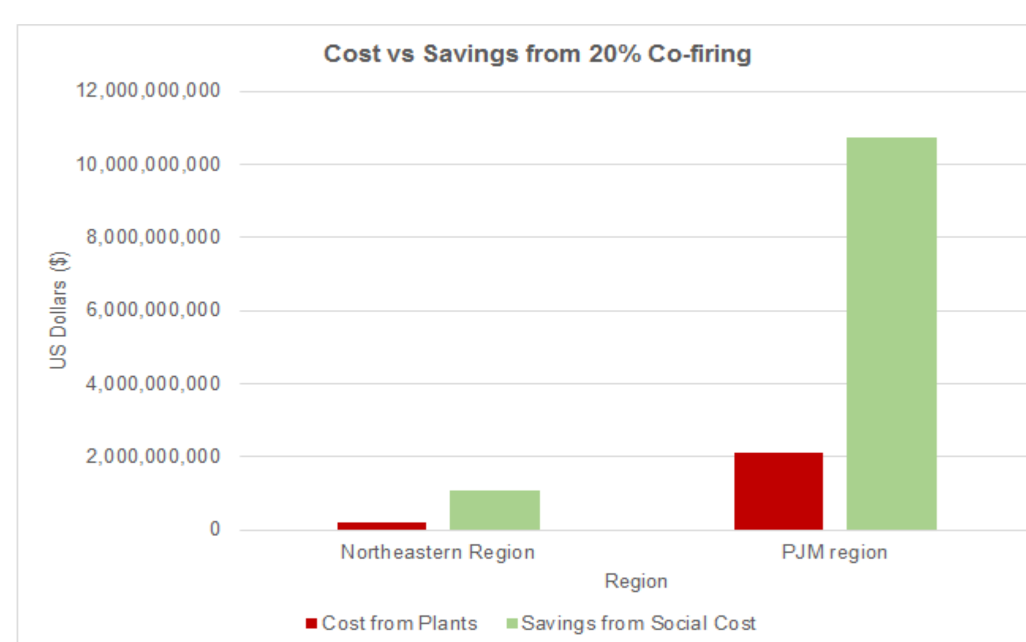


Figure 5. Extra cost from plants due to slight energy efficiency decrease (red) is outweighed by the massive social cost reductions from curtailing pollutants (green) in both regions of the USA.

- Northeastern region: Amount of money saved from 20% co-firing decrease in SO2, NOx, and CO2: 1,090,134,789 $
- PJM region: Amount of money saved from 20% co-firing decrease in SOx, NOx, and CO2: 10,741,381,685 $
- **Figure 5** Shows both regional benefits outweigh the cost when using biomass.

Figures 3 & 4 Represent the differences of Northeastern and PJM regions' pollution when co-fired at 20% biomass (green), versus using only coal (red). The plants chosen represent ordinary, coal fired power plants with nothing setting them apart from other plants in the region.

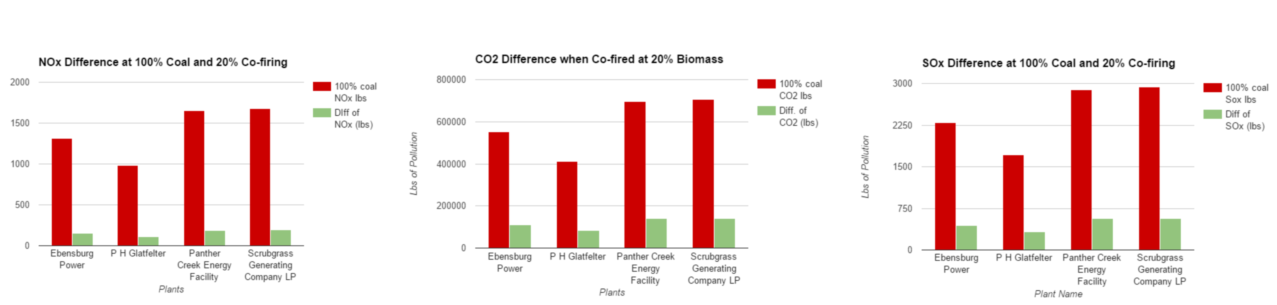


Figure 3. North Eastern Total regional pollution reduction: 19.98%

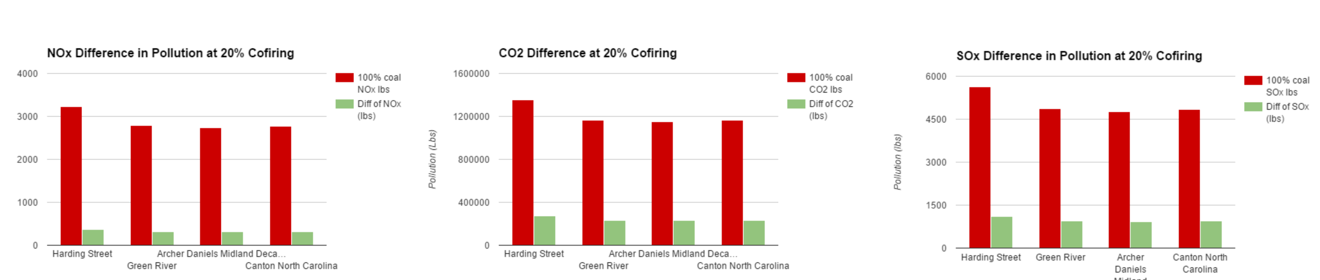


Figure 4. PJM Total regional pollution reduction: 19.98%

Future Direction

With the knowledge that co-firing biomass with coal leads to more economic benefits than costs, plant owners will be more willing to use co-firing to curtail pollutants. Besides economic benefits, there are health benefits from co-firing. NOx and SOx are known to cause respiratory issues, while also causing acid rain to harm wildlife and residential areas. The damages are estimated to be over five billion dollars, and come from tax payer money. CO2 makes up 80% of greenhouse emissions, and NOx is responsible for making smog that acts as an eye irritant. The large reduction of pollutants made from co-firing at only 20% coal reduction will achieve an economic advantage, as well as a healthier environment for humans to co-exist with the growing energy sector.

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