Co-firing Biomass to Reduce the Environmental Footprint of Coal-fired Heat and Power: A Good Strategy?

Greg Schivley, Troy R. Hawkins, Wesley W. Ingwersen, Joseph Marriott, Chris Sherry, and Timothy J. Skone

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Questions examined

1. How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?

2. When producing electricity, what is the life cycle effect of using 100% coal compared to co-firing with different types of biomass on selected impact categories?

3. Does the production of electricity and steam using combined heat and power (CHP) change the life cycle results when compared to electricity only?

4. Are results dependent on the co-product management method?
System description

• **Power plant**
  – New 200 MW circulating fluidized bed (CFB) facility, advanced control technology
  – 100% coal or 70% coal and 30% biomass feedstock
  – Biomass can be Inner Northwest (INW) roundwood, hybrid poplar, or forest residue
  – CHP provides 1,200 MJ of medium-pressure steam per MWh; displaces steam from a natural gas boiler or allocated by energy
  – CHP increases energy output per MWh by 33%; only requires 16% more fuel input

• **Feedstocks**
  – INW roundwood has 60+ year growth cycle; residue is burned
  – Hybrid poplar from corn belt
  – Forest residue representative of national average
  – National average of bituminous and subbituminous coal

• **Impact categories (TRACI 2.1)**
  – Global Warming Potential, Acidification, Eutrophication, Human Health Particulates, Smog Formation, Non-Renewable Energy
System diagram

Data sources:
- Coal, hybrid poplar, and forest residue feedstocks developed by NETL
- Roundwood feedstock developed by CORRIM
- Power plant performance data from NETL reports and public Virginia City Hybrid Energy Center data
- Natural gas boiler emissions from GREET
Questions

1. How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?

2. When producing only electricity (no-CHP), what is the effect of using 100% coal compared to co-firing with different types of biomass on selected impact categories?

3. Does the production of electricity and steam with combined heat and power (CHP) change the life cycle results when compared to electricity only?

4. Do different coproduct management methods change the results?
Biomass has a minor effect on stack emissions

- Higher CO₂ emissions (approximately 5%)
  - Lower energy-to-carbon ratio
  - On-site drying energy
- Minor increase in NOₓ emissions
- Slightly lower SOₓ emissions from reduced sulfur content
- Lower mercury emissions

Although biomass has lower sulfur and mercury content than coal, advanced control technologies in a new power plant allow the coal-only scenario to nearly match the lower sulfur and mercury emissions from the co-fire scenarios.
Questions

1. **How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?**

2. **When producing electricity, what is the effect of using 100% coal compared to co-firing with different types of biomass on selected impact categories?**

3. **Does the production of electricity and steam with combined heat and power (CHP) change the life cycle results when compared to electricity only?**

4. **Are results dependent on the co-product management method?**
Co-firing can increase non-GWP impacts

GWP is expected to be lower for all biomass types, but co-firing with hybrid poplar or roundwood raises other impacts (except non-renewable energy consumption).

Impacts from co-firing with forest residue are almost always lower than using 100% coal.

Life Cycle Impacts of Co-fire Systems Relative to Coal (Per MWh Produced)

- Global Warming Potential
- Acidification
- Eutrophication
- Human Health Particulate
- Smog
- Non-renewable Energy
Questions

1. How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?

2. When producing electricity, what is the effect of using 100% coal compared to co-firing with different types of biomass on selected impact categories?

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4. Are results dependent on the co-product management method?
Using CHP generally reduces impacts per MWh.

Displacement has higher particulate impacts.

Energy allocation has higher smog impacts.

Energy allocation is always 87% of the No-CHP case. Displacement varies by case.
A combined functional unit can make the total impacts easier to understand.

Differences in attributional results due to coproduct management methods disappear when steam impacts are added.

Coproduct management is an accounting system to determine impacts of a single product. Total results for all products from the system are always the same.
CHP does not substantially change GHG emissions

Cofiring with biomass can reduce life cycle GHG emissions.

Only minor difference in CHP/non-CHP GHG results.
Reduction in acidification impacts with CHP

Acidification Impacts (kg SO2-eq/MWh & 1,200 MJ Steam)

Coal and forest residue tend to have the lowest impacts. Roundwood impacts are largely from INW harvesting practices, hybrid poplar are from increased harvesting energy intensity and fertilizer production/use.
Biomass production impacts can be significant

Advanced control technology in the plant means that reduced sulfur content in biomass is not enough to overcome higher acquisition burdens for hybrid poplar and roundwood.
Significant PM impacts from INW roundwood

INW roundwood is the only feedstock with substantially different PM impacts, due to the practice of burning residue.
Natural gas adds substantially to smog impacts

**High NO\textsubscript{x} emissions from natural gas boilers and INW roundwood harvesting.**

![Bar chart showing smog impacts for different fuel and cofiring scenarios.](chart.png)
Conclusions

• Advanced control technologies mitigate the potentially lower stack emissions bio-based feedstocks might have due to lower sulfur/mercury content

• Co-firing with biomass can reduce GHG emissions and non-renewable energy use, but may increase other impacts depending on biomass type

• CHP increases the efficiency of energy production, generally reducing impacts per MWh when compared to only producing electricity

• Impacts from biomass feedstock acquisition can be significant, especially when compared to coal

• Combining functional units can provide clarity in results for some types of systems
Contact Information

NRMRL
www.epa.gov/nrmrl

Troy Hawkins, Ph.D.
Research Scientist
National Risk Management Research Laboratory
(513) 569-7139
hawkins.troy@epa.gov

NETL
www.netl.doe.gov

Timothy J. Skone, P.E.
Senior Environmental Engineer
Office of Strategic Energy Analysis and Planning
(412) 386-4495
timothy.skone@netl.doe.gov

Joe Marriott, Ph.D.
Lead Associate
Booz Allen Hamilton
(412) 386-7557
joseph.marriott@contr.netl.doe.gov

Greg Schivley
Associate
Booz Allen Hamilton
(412) 386-5818
greg.schivley@contr.netl.doe.gov