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

October 2, 2013

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?

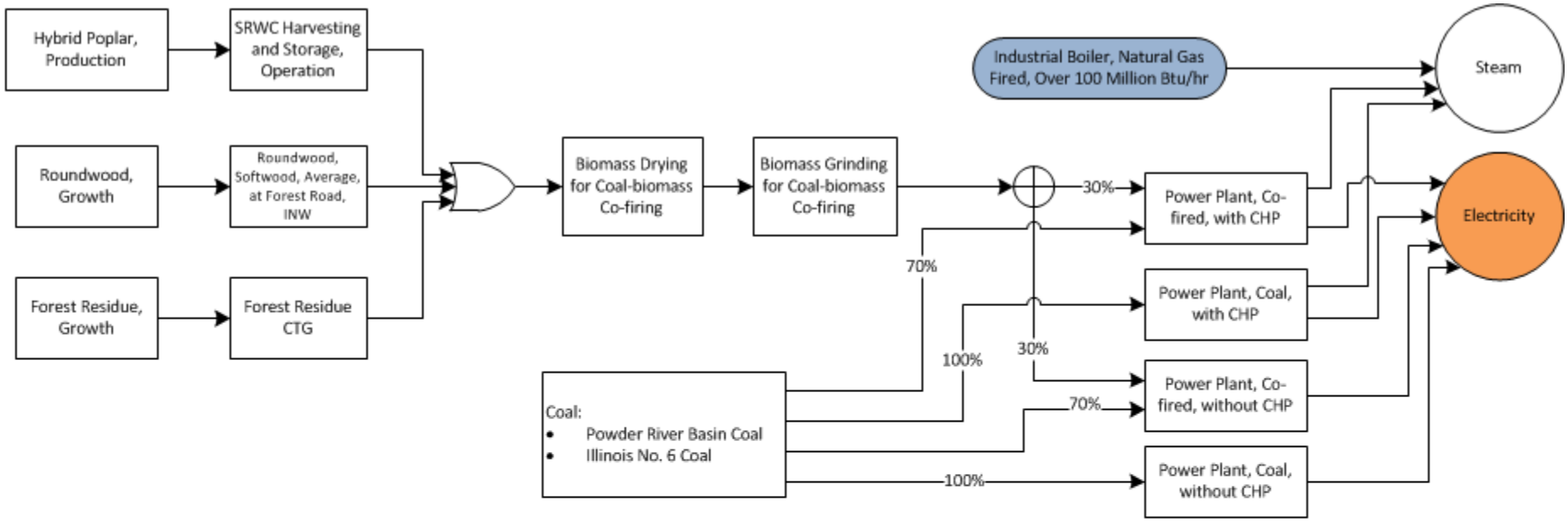
3. Does the production of electricity and steam using combined heat and power (CHP) change the life cycle results when compared to electricity only?

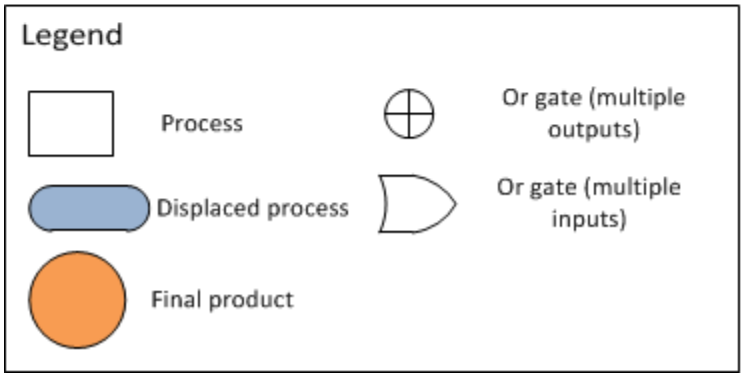
4. Are results dependent on the co-product management method?

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 CO_2 emissions (approximately 5%)**
  - Lower energy-to-carbon ratio
  - On-site drying energy
- **Minor increase in NO_X emissions**
- **Slightly lower SO_X 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

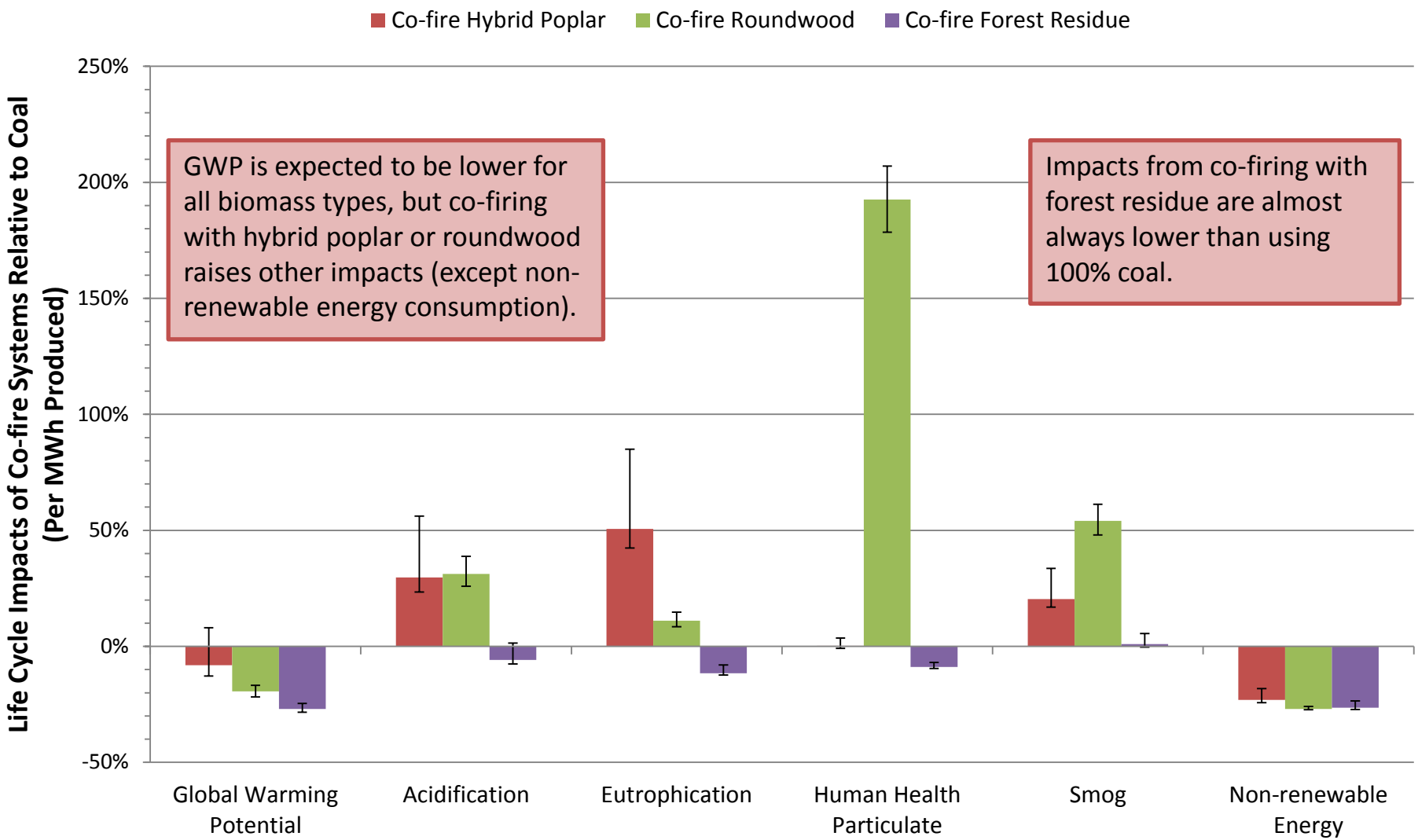
1. How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?

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



Questions

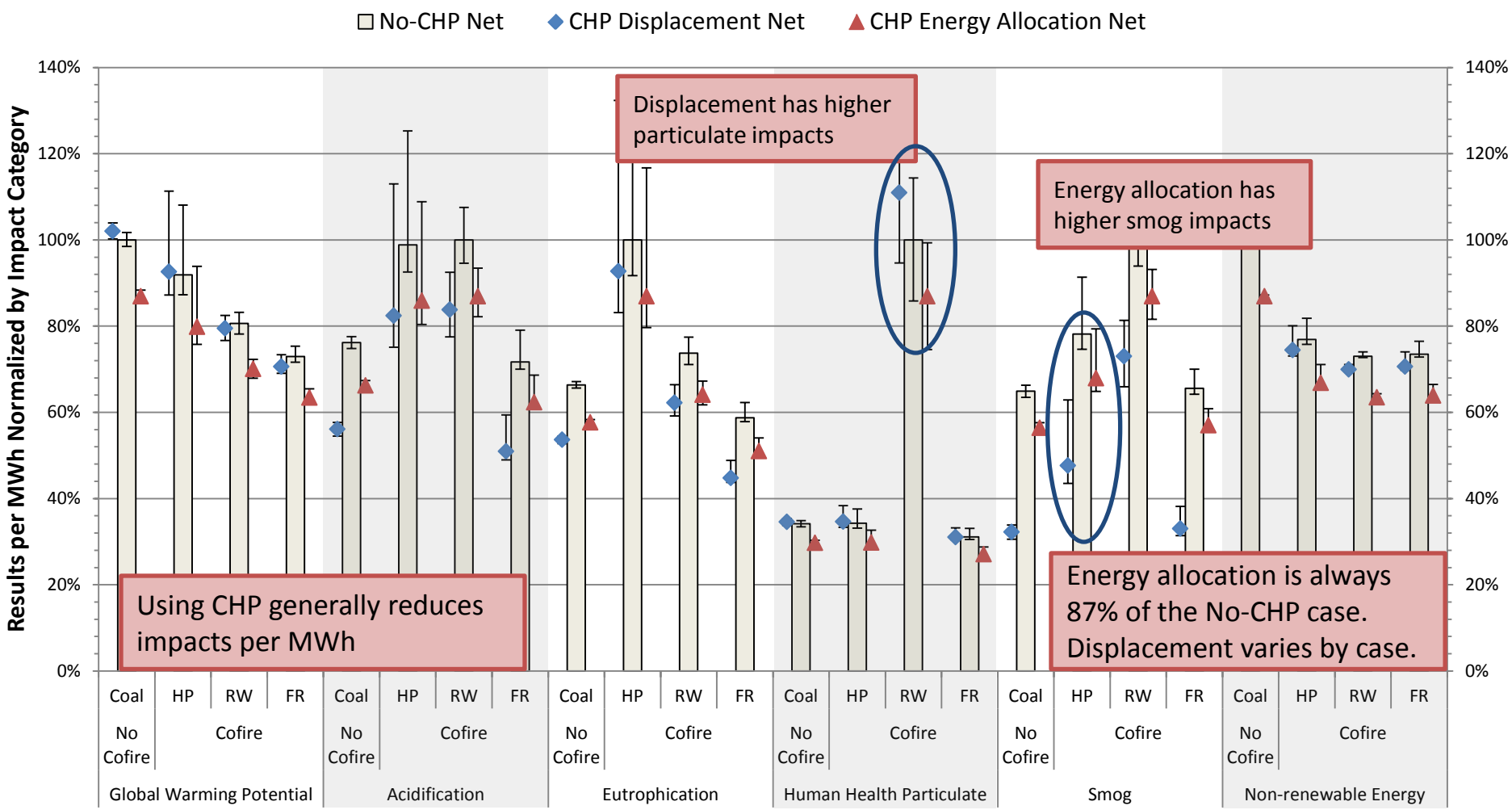
1. How does the use of biomass feedstock change stack emissions in a new power plant with advanced control technology?

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?

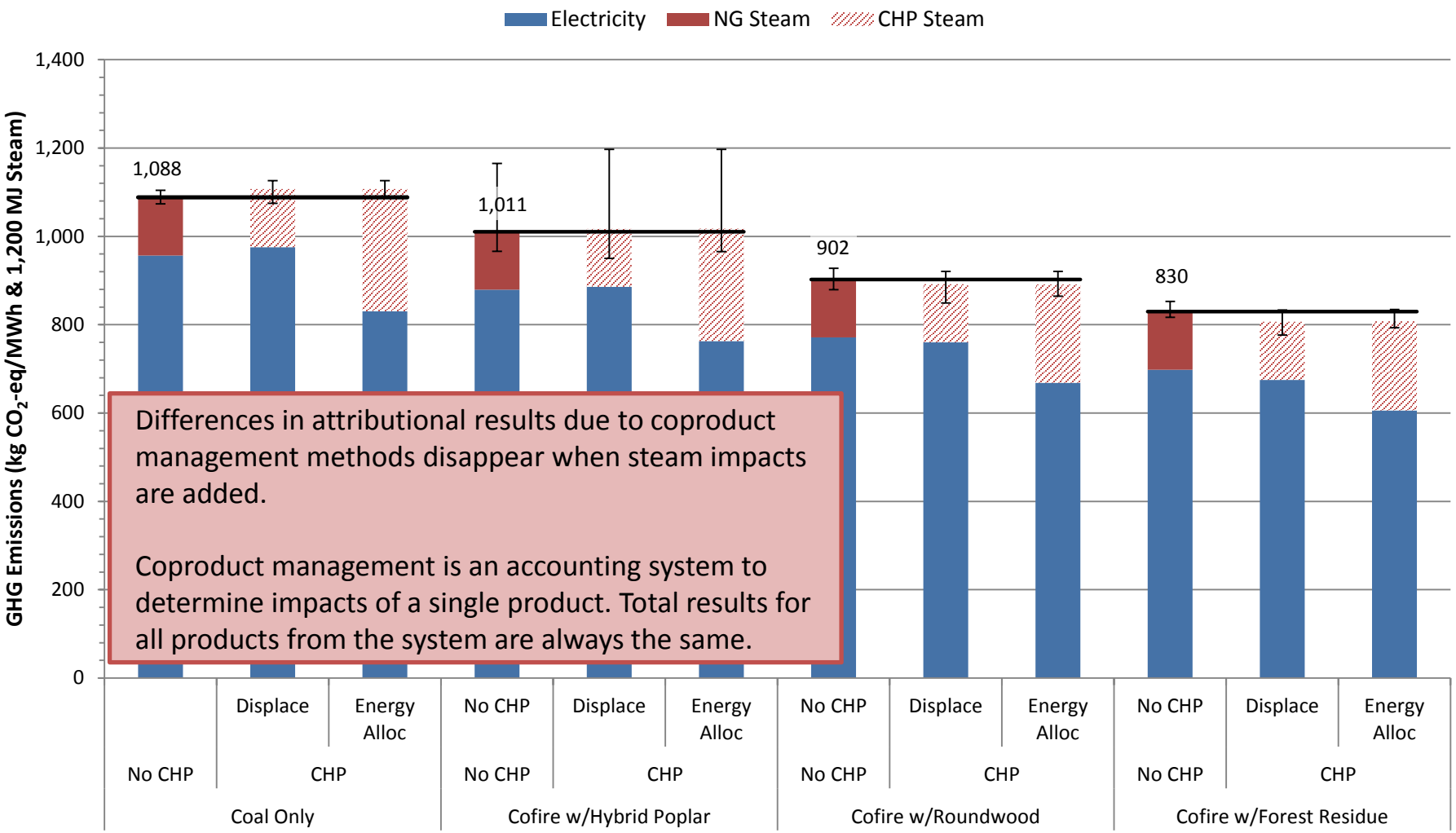
3. **Does the production of electricity and steam with combined heat and power (CHP) change the life cycle results when compared to electricity only?**

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

CHP generally lowers impacts – results vary depending on coproduct management method and impact category



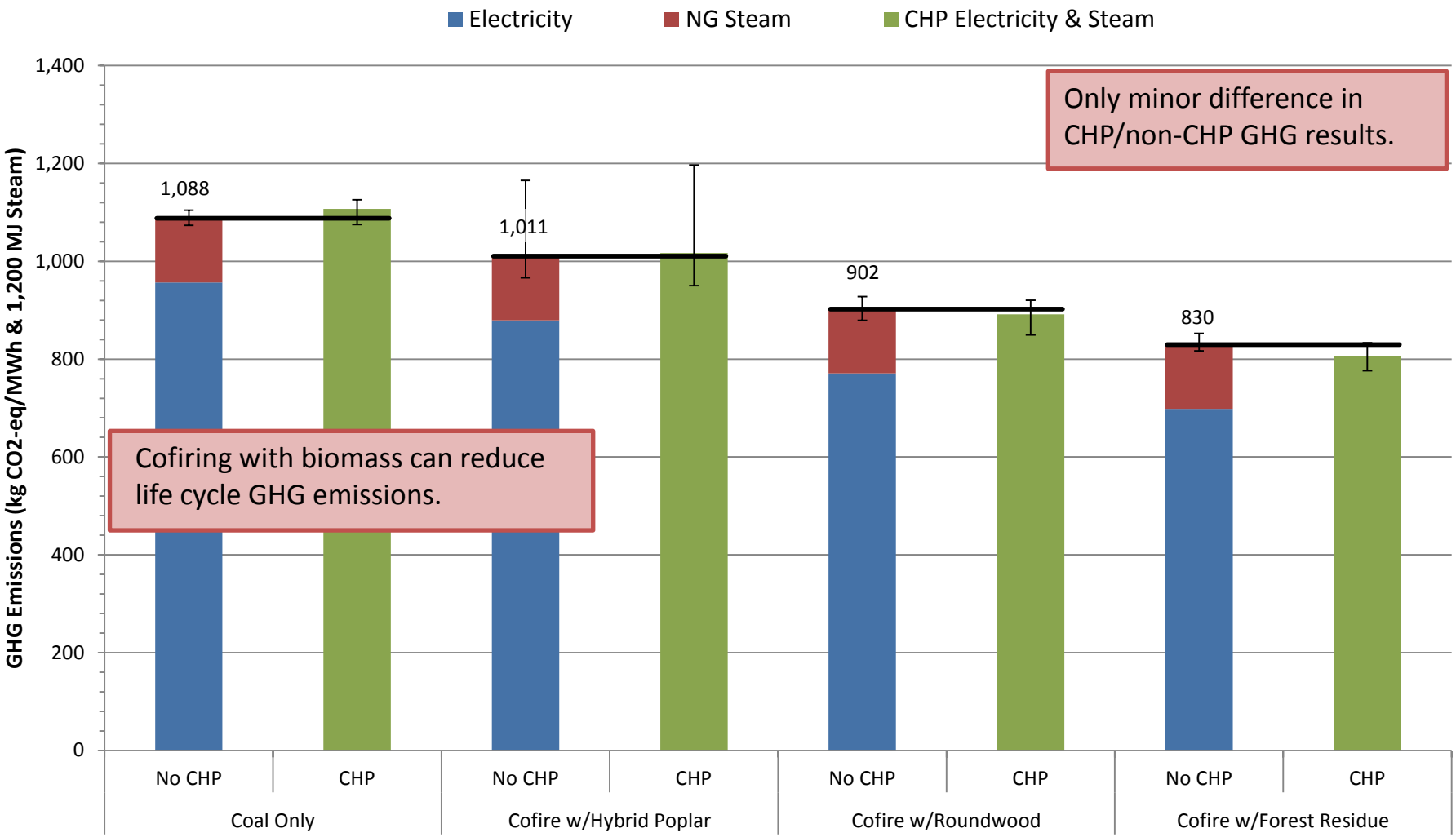
A combined functional unit can make the total impacts easier to understand



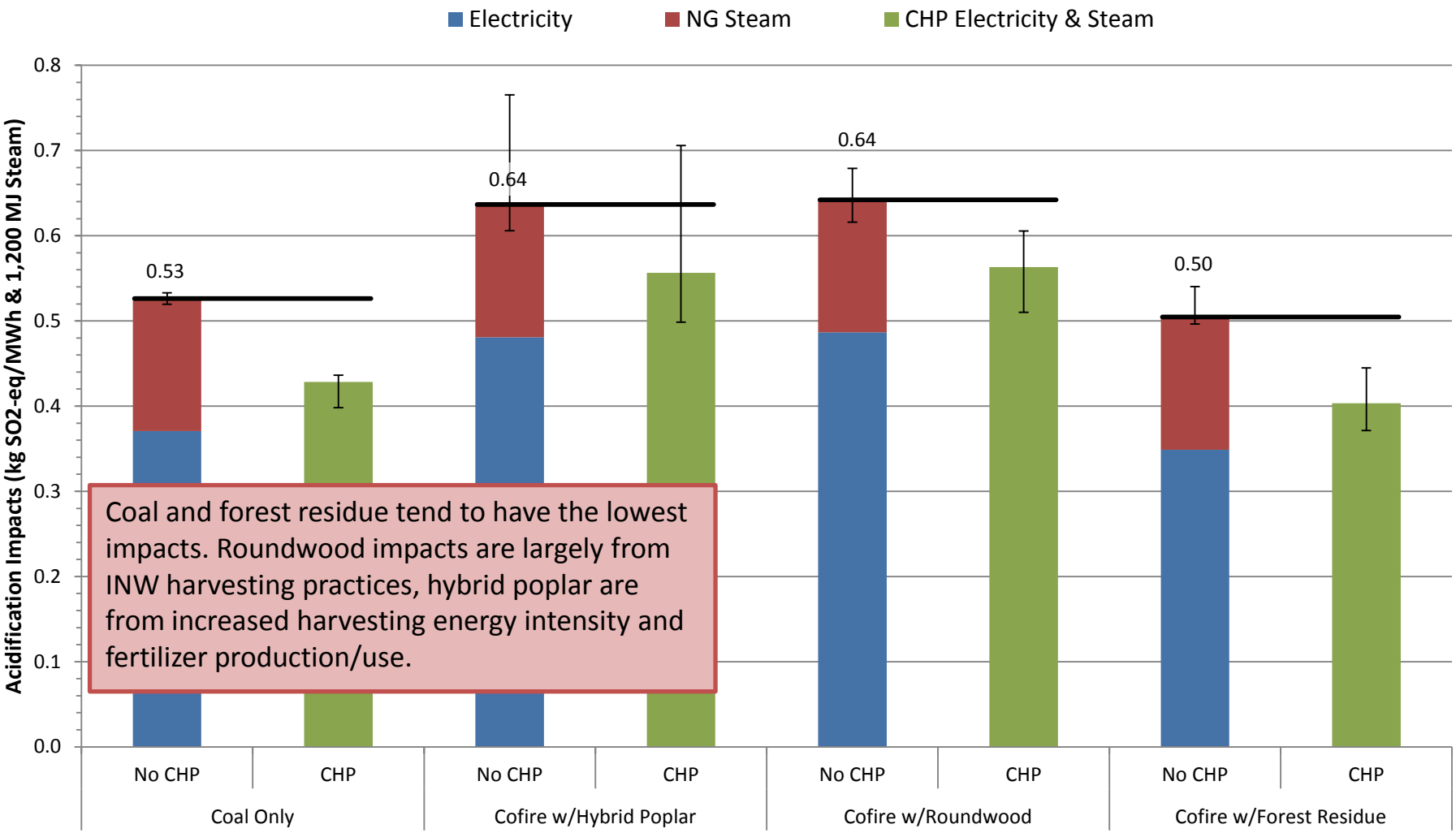
Differences in attributional results due to coproduct management methods disappear when steam impacts are added.

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

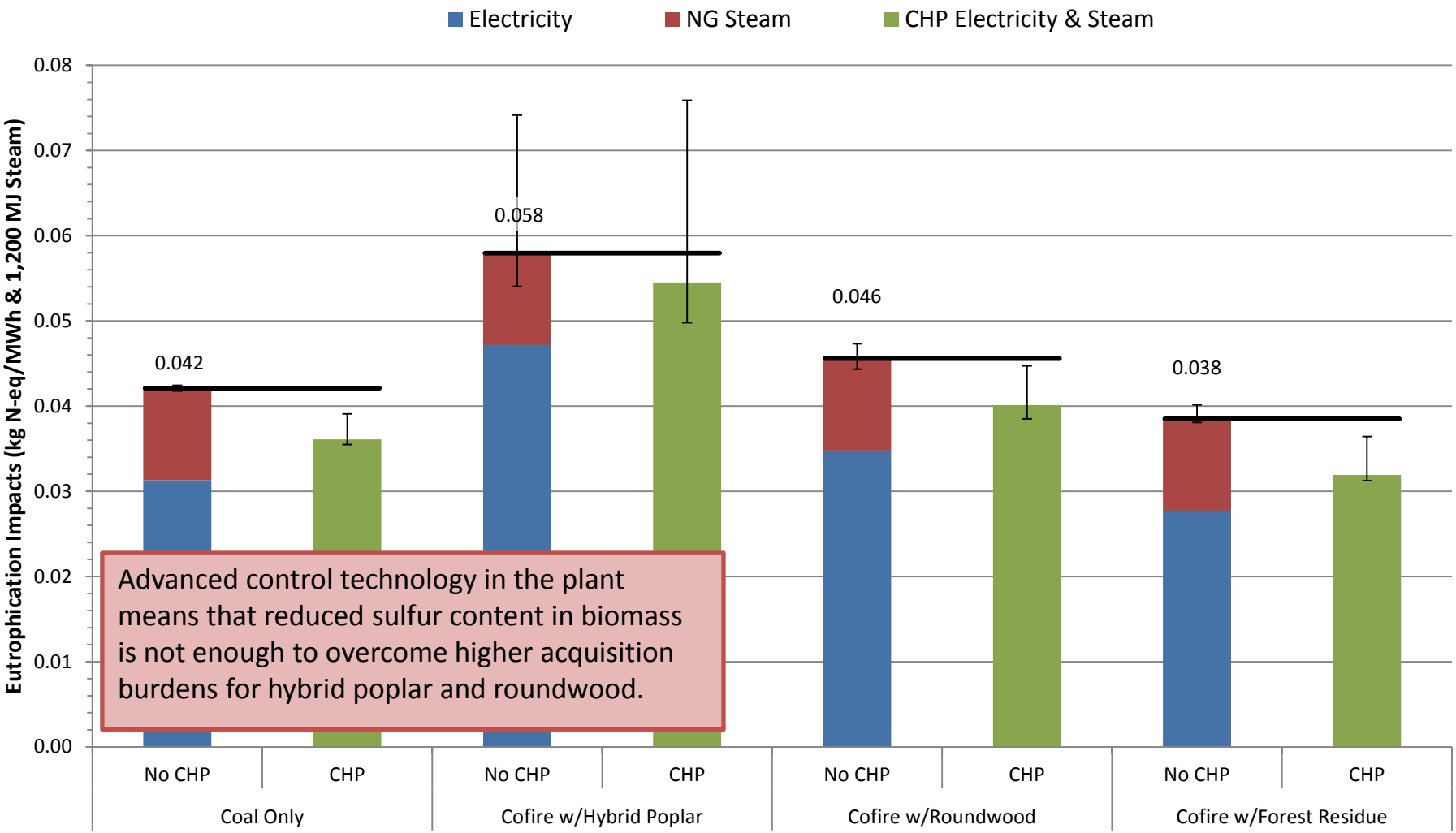


Reduction in acidification impacts with CHP



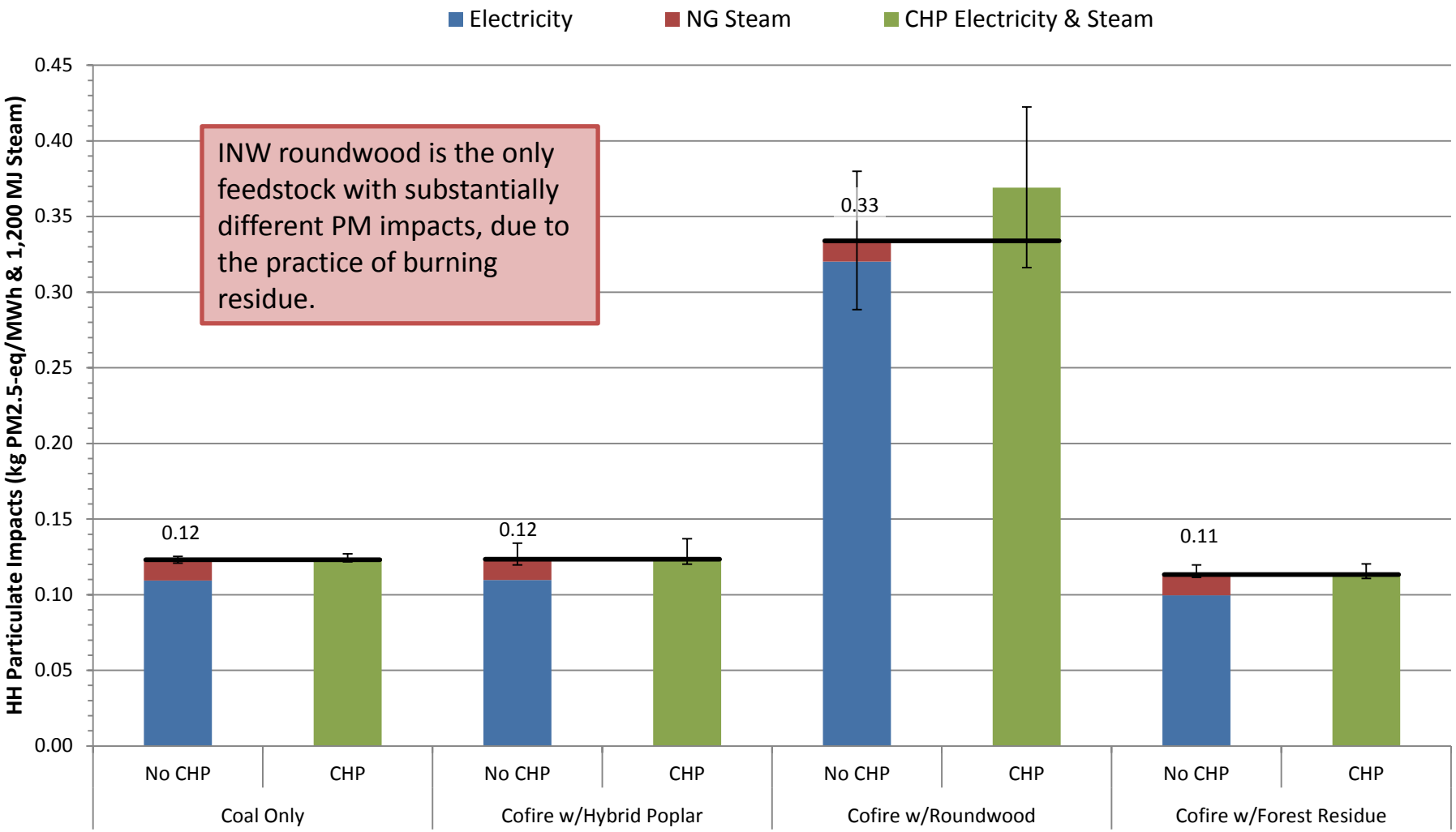
Coal and forest residue tend to have the lowest impacts. Roundwood impacts are largely from INW harvesting practices, hybrid poplar are from increased harvesting energy intensity and fertilizer production/use.

Biomass production impacts can be significant



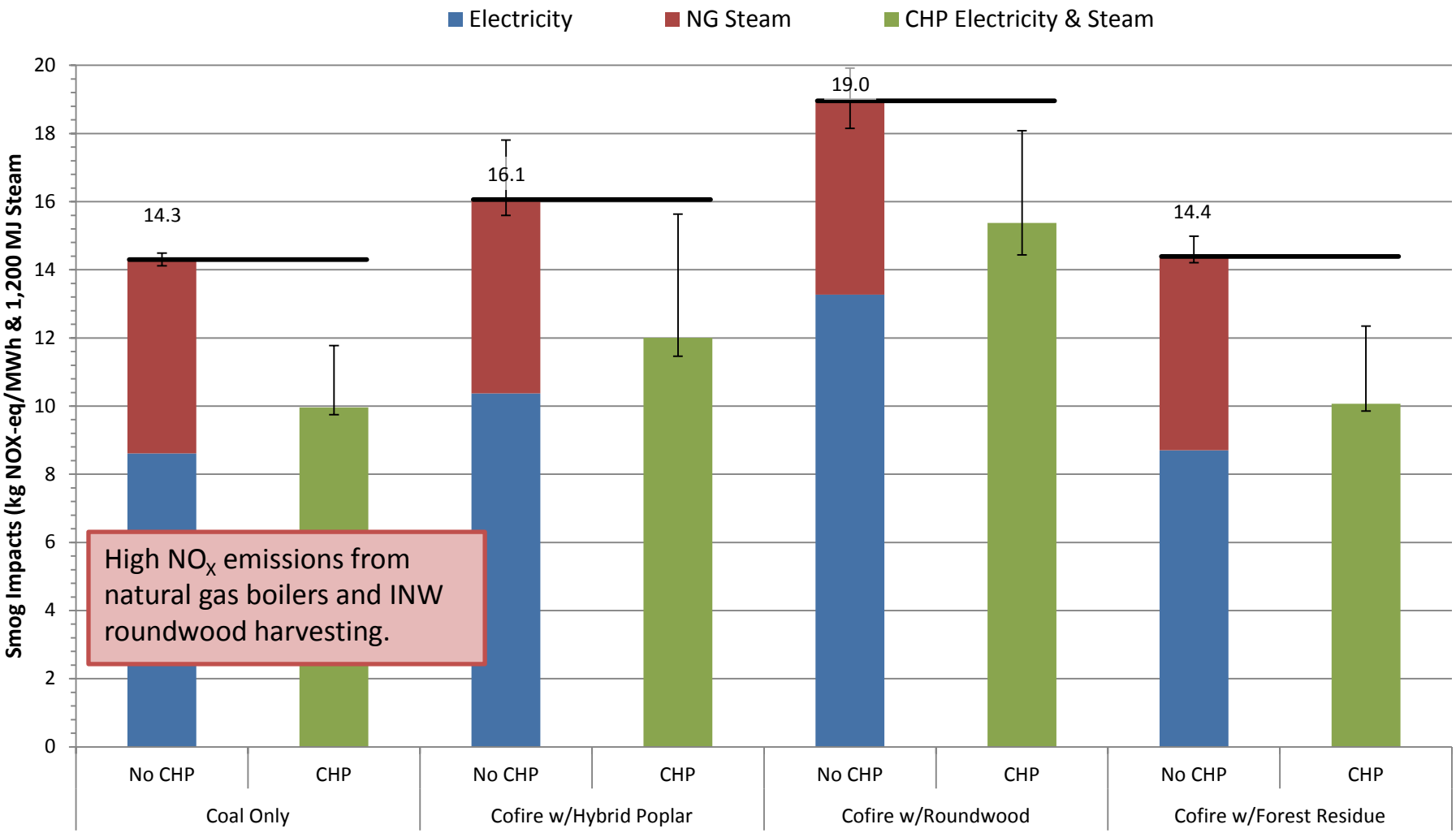
Advanced control technology in the plant means that reduced sulfur content in biomass is not enough to overcome higher acquisition burdens for hybrid poplar and roundwood.

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_X emissions from natural gas boilers and INW roundwood harvesting.

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

NETL

www.netl.doe.gov

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