the ENERGY lab

ANALYSIS FACTS

Life Cycle Analysis

Role of Alternative Energy Sources

Pulverized Coal and Biomass Co-Firing Technology Assessment

Project Description

This analysis evaluates the role of coal and biomass co-firing in the energy supply of the U.S. Co-firing is evaluated with respect to resource base, market growth, environmental profile, costs, barriers, risks, and expert opinions.

Resource Base and Growth

The resource base of co-fired power depends on the availability of coal and various biomass feedstocks, as well as the proximity of biomass sources to coal-fired power plants. As of 2011, active U.S. mines had 17.5 billion tons of coal ready for recovery. However, if current mining technologies are applied to the total resource base, the U.S. has estimated recoverable reserves of 261 billion tons of coal. Ninety-three percent of U.S. coal demand is for electricity generation (EIA, 2012). The U.S. has an extensive rail network that allows for economical, reliable transport of coal between mines and energy conversion facilities. Coal mines in the Western U.S. provide more than half of the U.S. coal supply (54 percent in 2011), followed by Appalachian and Interior mines (EIA, 2012). Based on an average annual coal demand rate of approximately 1 billion tons, the estimated recoverable reserves (261 billion tons) represent a 261-year supply of coal.

The three types of biomass that can be used for co-fired power are agricultural residues, forest residues, and herbaceous and woody energy crops. Corn and wheat offer the greatest supply potential for agricultural residues because they are the largest crops in the U.S. and have relatively high residue-to-grain ratios. Most forest resources are used by the forest products industry, as well as thousands of small businesses that make paper and wood products. Energy crops include perennial herbaceous crops and wood biomass such as hybrid poplar. The cost and logistics of biomass transport is the key barrier to the growth of the biomass resource base. Torrefaction is a viable technology for reducing biomass supply uncertainty and increasing the collection radius of a biomass resource, but does not translate to significant reductions in GHG emissions.

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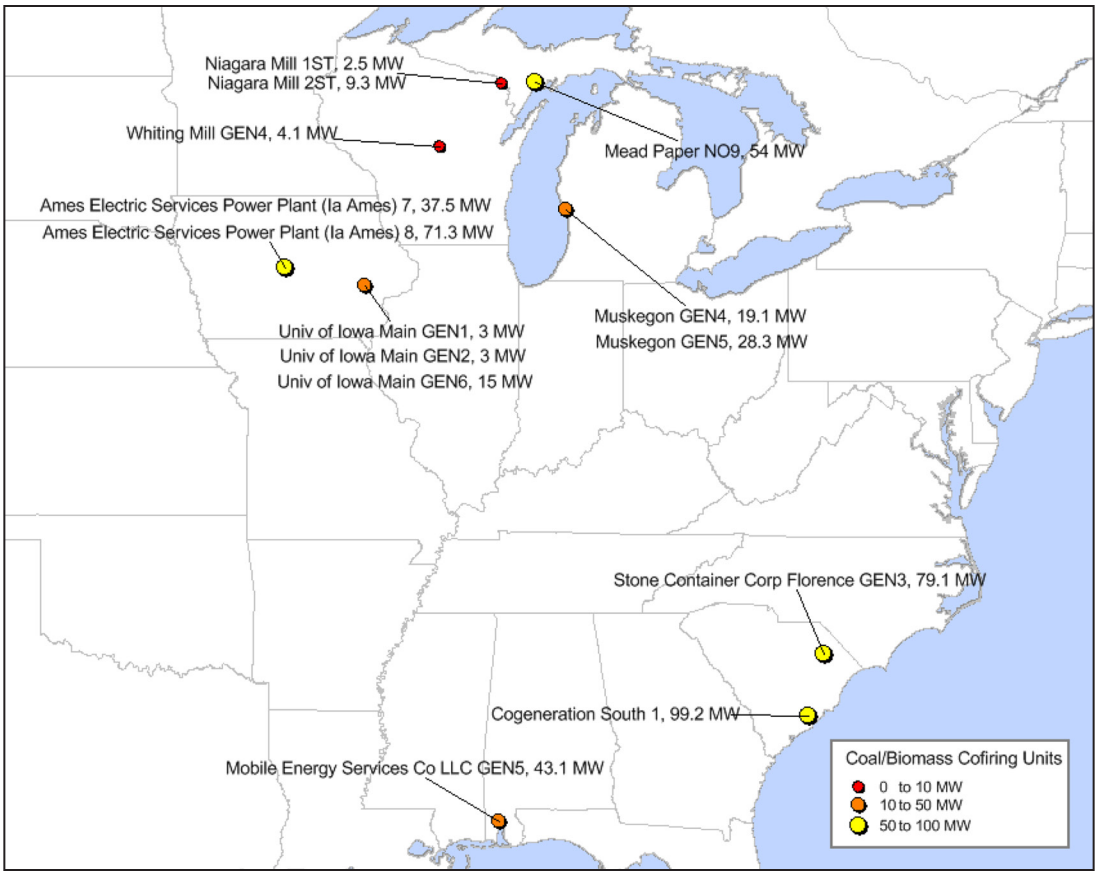
PUBLICATION INFORMATION

Publication Number
DOE/NETL-2012/1537

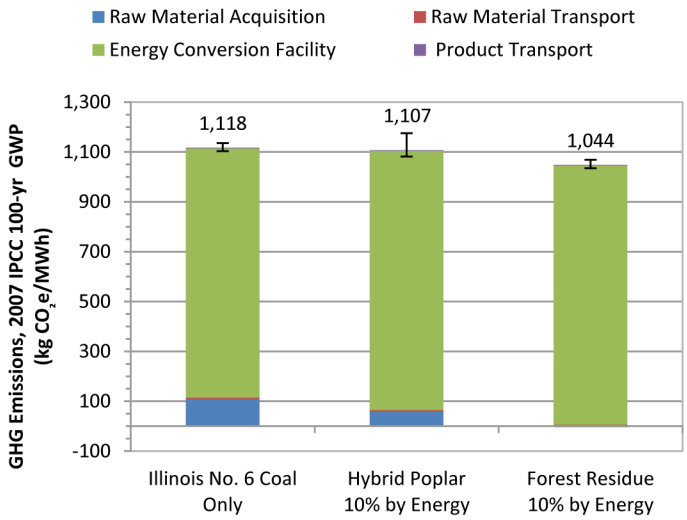
Publication Date
August 30, 2012



U.S. power plants that co-fire coal and solid biomass comprise 469 MW of installed capacity. These power plants are located in the Eastern U.S. and have single-boiler capacities ranging from 3 to 99 MW. EIA's Annual Energy Outlook projects significant growth in co-firing (EIA, 2012). This projection is contingent on low-cost biomass feedstocks and policies that encourage the use of renewable fuels.

Environmental Profile

The environmental profile is based on a life cycle analysis (LCA) that accounts for air emissions and resource consumption. The energy conversion facility is an existing power plant with a 550 megawatt (MW) pulverized coal boiler and a net efficiency of 33 percent. When the system combusts hybrid poplar (an energy crop) at a 10 percent share of feedstock energy, the life cycle greenhouse gas (GHG) emissions are reduced by only one percent. Most of the GHG reductions due to the displacement of coal are offset by the land use, fertilizer, and efficiency losses of co-firing. The co-firing of forest residue is more effective at reducing GHG emissions than hybrid poplar. When forest residue is co-fired at a 10 percent share of feedstock energy, it reduces life cycle GHG emissions by 6.6 percent. The key advantage of forest residue, in comparison to hybrid poplar, is its low GHG emissions for material acquisition.



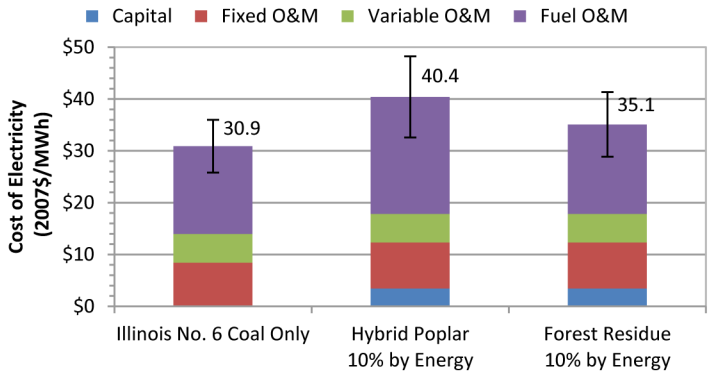
A scenario for torrefied biomass was also modeled. Torrefaction is a mild pyrolysis that alters the physical properties of biomass. The life cycle GHG emissions from the co-firing of torrefied poplar at a 10 percent share of feedstock energy are 1,071 kg CO_2e/MWh. This result is 4.2 percent lower than the coal-only scenario and 3.3 percent lower than the hybrid poplar (untorrefied) co-firing scenario, but 2.6 percent higher than the co-firing of forest residue.

The results for other air emissions show that co-firing increases the life cycle lead (Pb), volatile organic compounds (VOC), and particulate matter (PM) emissions. Co-firing reduces life cycle sulfur dioxide (SO_2) emissions if forest residue is used, but not if hybrid poplar is used. Co-firing does lead to reductions in life cycle emissions of carbon monoxide (CO), nitrogen oxides (NO_X), and mercury (Hg).

Costs

The cost profile of co-fired power is based on a life cycle cost (LCC) model with a 50/50 debt to equity ratio, accelerated depreciation, and a required return on equity of 12 percent. The fuel prices for coal, hybrid poplar, and forest residue are $1.64, $4.27, and $1.73 per gigajoule (GJ), respectively. (These fuel costs are representative of the 2010 market but are expressed in 2007 dollars.) The operating and maintenance (O&M) costs are similar to those for a typical subcritical pulverized coal power plant, with slight adjustments to account for the labor required to run and maintain biomass handling systems.

The retrofit of an existing PC plant to co-fire hybrid poplar at a 10 percent share of feedstock energy increases the COE from $30.9/MWh to $40.4/MWh (a 31 percent increase). If forest residue is co-fired instead of hybrid poplar, the increase in COE is only 14 percent. The capital costs of the co-fired systems account for a small share (approximately 8 percent) of the COE because this analysis assigned capital costs only to new equipment, not existing equipment. The key drivers of cost uncertainty are the feedstock prices for coal and biomass.



Barriers

The technical barriers to the implementation of co-firing systems include biomass supply uncertainty, higher-than-expected decreases in boiler efficiencies, equipment fouling, and co-product degradation.

The above barriers can be resolve in part by torrefaction. The improved physical characteristics of torrefied biomass make long-distance transport more economical, which increases the radius of collection for biomass and, in turn, reduces supply chain uncertainty. However, as shown by the environmental model of this analysis, torrefaction does not significantly improve the GHG profile of co-fired systems.

Risks

Regulatory uncertainty is a key risk of implementing co-fired power systems. State level directives and plans, which are still in development, are essential for moving government toward regionalized support for increased biomass collection and utilization. Since sourcing of biomass is a major concern for many energy facilities that rely on biomass, additional regulatory developments that support biomass collection and use would help support the growth of co-firing.

Expert Opinions

These above barriers and risks are echoed by expert opinions that are summarized in a recent report by the RAND Corporation. According to RAND's research, the long-term effects of biomass co-firing on installed process equipment are not known. The same report also notes that the future of co-firing is dependent on the facilities being able to receive renewable energy credits for the practice because of the operating and capital costs of biomass relative to coal. (Ortiz, et al., 2011)

References

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