Economic and Environmental Analyses of Coal Biomass to Liquids: A Case Study in West Virginia

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Objectives:

1) Develop an integrated linear model to optimize the economics of CBTL.
2) Perform a LCA study to analyze the environmental benefits.
3) Conduct sensitivity analysis of economic and environmental impacts of the CBTL strategies under different scenarios.

Data and Methodology:

Biomass: Billion Ton Study;

Coal: Annual Coal Report;

Mix Ratio: Biomass to coal (w.b.) - 0/100, 8/92, 15/85, 20/80, 25/75, 30/70;

CBTL Model: It is to maximize the total profits from the CBTL biofuel production based on feedstock availability and related costs.

$$\boldsymbol{Max\ z} = Rv - TC.$$

$Where:$

$$TC = Pu + Tr + \psi \cdot OM + \zeta \cdot TPC.$$

$$Pr = p_f \sum_{t}^{T} \sum_{p}^{P} (\sum_{c}^{C} c_c \cdot xC_{cpt}$$

$$+ \sum_{i}^{I} c_b \cdot xI_{ipt} + \sum_{s}^{S} c_b \cdot xS_{spt}).$$

$$Pu = \sum_{t}^{T} \sum_{p}^{P} (\sum_{c}^{C} p_c \cdot xC_{cpt}$$

$$+ \sum_{i}^{I} (p_l + HC) \cdot xI_{ipt} + \sum_{s}^{S} p_s \cdot xS_{spt}).$$

$$Tr = \sum_{t}^{T} \sum_{p}^{P} (\sum_{c}^{C} t_c \cdot dC_{cp} \cdot xC_{cpt}$$

$$+ \sum_{i}^{I} t_l \cdot dI_{ip} xI_{ipt} + \sum_{s}^{S} t_s \cdot dS_{sp} xS_{spt}).$$

Life Cycle Assessment: The boundary of this LCA study was shown in Fig. 1. The functional unit is 1,000 MJ energy equivalent FT liquid fuels. The impact of GHG emissions was calculated using 100-year global warming potentials. The calculation of blue water consumption (BWC: kg) was based on the method developed by Boulay *et al*. Fossil energy consumption (FEC: MJ) was calculated using the method developed by Frischknecht *et al*.

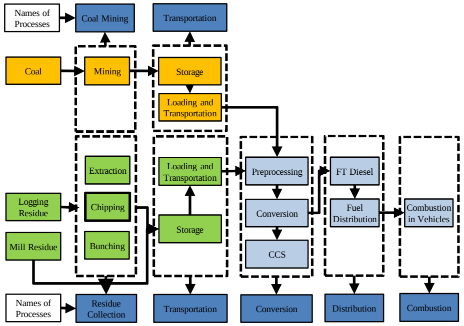

Fig. 1. System boundary of the CBTL LCA framework model.

Sensitivity Analysis: Price of coal ($40 ton^{-1}-$100 ton^{-1}); price of biomass ($40 ton^{-1} - $140 ton^{-1}); energy efficiency (40%-50%); IRR (10%-20%); mix ratio; capital cost.

Results:

Siting and Capacity: The productivity of all plants with optimized siting decreased with decreasing energy efficiency and with increasing mix ratio (Fig. 2-a). The highest productivity was 480,000 bbl/day (bpd) with highest energy efficiency and no biomass.

Economic Impacts: In the base case, the purchase of coal accounted 60.7% of the total cost. Operational and maintenance cost accounted 17%. The required selling price (RSP) was $103.4·bbl^{-1}. The lowest RSP was $90.04·bbl^{-1} when the mix ratio was 0/100 at the maximum energy efficiency. The highest RSP was $144.13 ·bbl^{-1}when the mix ratio was 30/70 (Fig. 2-b).

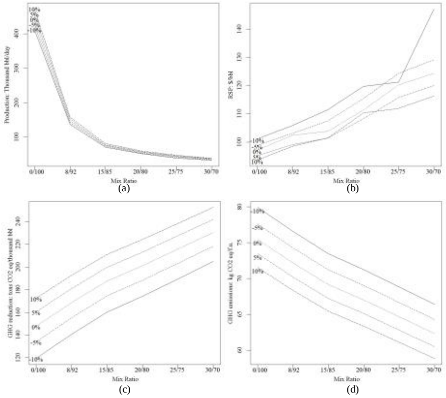

Fig.2. Sensitivity analyses by energy efficiency and biomass to coal mix ratio for CBTL fuel production in thousand bbl/day (a); required selling price of CBTL fuels $/bbl (b), GHG emission kg CO_2 eq/f.u. (c),and GHG reduction compared to petroleum derived diesel in thousand tons CO_2 eq/year (d).

Environmental Impacts: Most GHG emissions were contributed by combustion in vehicles and thermal conversion at the CBTL facilities, which were 68.49% and 14.85% respectively. The GHGs were 78.99 kg CO_2 eq and ranged from 56.4 kg CO_2 eq to 98.2 kg CO_2 eq for different scenarios. Most of the water and fossil energy were consumed in the conversion process.

Summary:

- The RSP increases with increasing biomass/coal ratio.
- Biomass is the limiting factor for operating a CBTL plant.
- Low energy efficiency leads to high RSP.
- The major contribution of GHG emissions is from the conversion of FT fuels and combustion.
- High energy efficiency and reliable supply chain are essential to compete with fossil fuel.

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