Domestic Energy Parks: An Approach to Producing Low Carbon Energy Products from Domestic Resources by Leveraging Infrastructure at Existing U.S. Pulp and Paper Mills

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Abstract

Faced with growing energy demand, national energy security concerns, and looming legislation to regulate CO_2, the U.S. must grapple with a multitude of issues when examining its future energy supply. The current political focus is on a strong push to develop an industry around domestically sourced and produced, low-carbon liquid fuels and electricity. In this essay, we investigate the potential to retrofit the equipment of an existing pulp and paper facility with gasification technologies to create an "Energy Park" that cost effectively blends coal and biomass to produce a suite of low-carbon energy products in addition to its core fiber industry outputs. Historically, the pulp and paper industry has been one of the most energy intensive industries in the U.S, and currently confronts increasing competition in the expanding globalized marketplace. The system model presented here explores options for the industry to become a first mover of a technology platform that offers significant potential benefits but currently faces deployment hurdles.. By utilizing existing infrastructure and energy handling capabilities, and taking advantage of important access to transmission, rail, and markets, the pulp and paper industry could provide a unique, albeit limited, opportunity to commercially demonstrate advanced gasification technologies that could then be applied on a larger scale in new greenfield applications.

Introduction

Energy demand in the United States continues to grow along with an ever expanding reliance on imported sources, such as crude oil, natural gas, and refined petroleum products. With current oil prices at all time highs and with increased volatility in the global oil marketplace, there is heightened anxiety concerning the energy and economic security of the U.S. Consequently, there is increasing political and public momentum to diversify both the nature and geographic disposition of the U.S. energy mix, in particular focusing on domestic, low-carbon supply alternatives to petroleum. This is evidenced by the recent passage of the Energy Independence and Security Act of 2007, which includes an ambitious renewable fuel standard (RFS) in addition to important fuel efficiency and conservation measures. Although recent efforts to expand domestic supply have focused on corn-fermentation ethanol, by specifying a requirement for advanced biofuels, the Energy Independence and Security Act of 2007 demonstrates mounting recognition that corn-based ethanol has limited potential in the long term. Because corn ethanol offers only marginal net energy benefits and small GHG emissions reductions, imposes upward pressures on food prices, and draws large subsidies, other low carbon, domestic fuels will be needed. While advanced biofuels, like cellulosic ethanol, hold tremendous potential in terms of the net energy gains and GHG reductions, technological and economic hurdles have thus far limited commercial production. Even with a mandated market, advanced biofuels, too, will most likely face economic and scaling challenges, at least in the infancy of commercial deployment. At the same time, domestic electricity demand continues to escalate while siting new electricity generation projects faces mounting hurdles. Cleary, there is a critical need to find and develop secure, domestic energy resources that can simultaneously supply both electric power and transportation fuels in a manner that limits emissions of GHGs and is cost effective without subsidies.

Two of the most abundant energy resources found in the U.S. are coal and biomass. The Department of Energy estimates U.S. recoverable reserves of coal at more than 250 billion short tons. Although more speculative, DOE and USDA estimate that over 1 billion dry tons of biomass could be available in the U.S. with modest changes in land use and agricultural and forestry practices. For context, in 2006, the U.S. consumed over 1.1 billion short tons of coal and over 200 million dry tons of biomass for product and energy production. Because coal intrinsically contains a large amount of carbon and other impurities, energy projects relying on coal as the sole energy feedstock face considerable obstacles in siting and financing. This is evidenced by strong public opposition to both new pulverized coal electricity plants and coal to liquids projects. Conversely, biomass theoretically offers many carbon advantages if advanced energy conversion techniques can be

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See footnotes at end of text.

commercialized, particularly if its use is coupled with carbon capture and storage (CCS). Because of this, co-utilizing biomass with coal could offer climate and security enhancing energy products. The challenge is to bring these products into the marketplace at a competitive cost.

One avenue holding particular promise is to produce liquid fuels and electricity building on equipment already in place in the pulp and paper (P&P) industry. The P&P industry provides a well suited infrastructure to incorporate advanced technologies and expand production into energy products such as transportation fuels, electricity and other chemicals in addition to its core products. The industry also has substantial experience with handling large quantities of biomass and ready access to fuel and electricity marketing infrastructures. Several recent studies have explored the idea of producing energy products such as liquid fuels and electricity at P&P mills by processing additional biomass—a concept referred to as a *biorefinery*. The results from these studies are positive: liquid fuels and electricity can be produced at costs comparable with current market prices and with high environmental standards, including low lifecycle GHG emissions. However, because of technology limitations and biomass availability constraints, the scale of energy production would be relatively small. But an area identified as deserving of additional analysis was the idea of scaling up the size of the facility through co-firing coal and biomass to increase the output of energy products at lower unit costs. Such a system would also need to employ carbon capture and storage (CCS) to minimize the additional GHG emissions stemming from coal. This type of facility is referred to as an *energy park* and, in our view, shows great potential as a platform for first-movers of biomass and coal gasification technologies. Preliminary analysis of the energy park concept finds that this business model has the potential to produce greater volumes of liquid fuels and larger amounts of exportable electricity at lower unit costs compared with a biorefinery. Further, combined with CCS, an energy park also is capable of producing energy with GHG intensities potentially better than conventional petroleum and power generated from a typical pulverized coal plant, respectively. The bottom line is that by utilizing innovative technologies—such as gasification, steam reformation, and CCS—domestic coal and biomass have the potential to contribute to the country's energy demands, environmental objectives, and energy security imperatives concurrently. Implementing these technologies at an existing P&P facility could provide the circumstances for leveraged efficiencies and capital that push these systems in the realm of economic competitiveness, even in an environment without subsidies.

Why Pulp and Paper Mills?

Several attributes make the P&P industry uniquely positioned to be a first mover in testing advanced gasification systems. For instance, the P&P industry represents one of the most energy-intensive industries in the United States, but, unlike other industries that fall into this category, such as manufacturing and chemical production, the majority of the energy consumed is generated from renewable biomass by-products from the pulp production. In fact, the P&P industry is by far the largest producer and user of biomass energy in the country. Because of this, the P&P industry has core competencies harvesting, transporting, and processing biomass. Furthermore, the P&P business model generally ensures that mills are surrounded by large land buffers, which represents an underutilized capital asset that could be very important in this era of infrastructure siting challenges. Also, P&P mills are typically on major road and waterways, which provide robust access to the electrical and transportation grid and are often in close proximity to oil refineries or other markets.

Additionally, the significant majority of Tomlinson boilers—a key capital component of a P&P mill—are over 40 years old and need to be replaced over the next decade. This capital turnover creates an opportunity for basic process changes and the implementation of new technologies such as gasification and steam reformation technologies both of which can dramatically increase the thermal efficiency of the pulping production process. In fact, the demand for steam at a P&P mill creates a significant heat sink that cogeneration of steam and electric power can fill. Also, by adding extra capacity to the gasifier system, it is possible to process additional biomass—such as mill waste, agricultural by-products, or municipal sewage sludge—and coal in order to create synthetic energy products for exportation thereby expanding into non-traditional P&P markets. This additional gasification capacity enables the mill to produce a syngas—a synthetic fuel that is readily converted to liquid fuels (such as diesel), electric power, or some combination of the two. In essence, this process—integrating oversized gasifiers at existing P&P mills for synthetic fuel and electricity production in addition to its traditional paper products—is the biorefinery/energy park concept. But because U.S. P&P mills have recently experienced diminishing financial performance as a result of global paper overcapacity and tough price competition from importers, this capital expansion has been slow to attract investors. However, it is our view that domestic P&P mills should seriously explore these options to reduce energy and chemical costs and leverage existing assets to build new revenue streams. To date, most industry investments have focused on restructuring existing production assets, but by making strategic investments in gasification technologies and process integration, the P&P industry has an opportunity to stabilize its core business while expanding into new markets. This experiment could provide a fertile testing ground for advanced gasification technologies, while also increasing domestic energy supplies in a climate sensitive manner. Furthermore, this expansion could also help rekindle rural economic growth in areas where the P&P production has declined.

Building on the Biorefinery Business Model

A comprehensive study by Larson et al. (2006) entitled "A Cost-Benefit Assessment of Gasification-Based Bio-refining in the Kraft Pulp and Paper Industry" assessed the engineering and financial potential of upgrading existing Kraft-process P&P mills by replacing their Tomlinson black liquor boilers with high pressure gasification or steam reformation technologies and using kraft black liquor and other biomass to create liquid fuels, electricity, and other chemical products. [1] Gasification technologies permit a biorefinery to produce a syngas that can meet the thermal energy and steam requirements of the P&P mills and generate liquid biofuels on the order of 1,500-4,500 barrels per day and a small amount of exported electricity as supplementary products. Depending on plant configuration, the biorefinery can produce three types of liquid fuels—Fischer Tropsch liquids (FTL), dimethyl ether (DME), and mixed alcohols—in addition to generating electricity. Because biomass serves as the key energy input for a biorefinery, important environmental benefits, in particular GHG emissions, reductions can be realized, even without CCS. In fact, the total CO_2 emissions and criteria pollutants are lower than modern Tomlinson boiler configurations because of higher overall thermal efficiencies. Furthermore, all of the component technologies needed for gasification-based biofuel production at a biorefinery are either already commercially used or are undergoing pilot-scale demonstration. The authors concluded that while the biorefinery mill modifications would require substantial capital investment, they would reduce the mills energy cost vulnerability, help control product cost, and increase product cash flow.

The authors of this study focused on a biomass only approach and highlighted the possibility that larger scale biorefinery plants, realizing economies of scale by blending the biomass with coal feedstocks, could actually be more conducive to producing large quantities of liquid fuels in the long-term. They note that an important element of this configuration would be the ability to include CCS. Sequestering CO_2 is essential given coal's carbon intensity – and if combined with the potentially large carbon benefits associated with CCS of biomass of recent photosynthetic origin, the carbon balances could become quite attractive. This system model is explored more below.

The Farmer and Coal Miner Could Be Friends: Energy Parks

Building on the biorefinery model, a study conducted by Rezaiyan, A.J. et al. (2007) entitled "Domestic Energy Parks – Filling the Transportation Void" and sponsored by the University of North Dakota Energy and Environment Research Center and in part by our organization, the National Commission on Energy Policy, sought to assess the business model of the so-called *energy park*—a scaled-up biorefinery co-utilizing coal and biomass with CCS to maximize the production of liquid fuels while adhering to strict CO_2 controls. [2] Such a facility would produce on the order of 14,000-17,000 barrels of FT diesel and 350-550 MWhr of exportable electricity per day. This study assessed the engineering potential and financial viability of different energy park plant configurations in four U.S. regions (South, Northeast, Midwest, and West). Regional variation enabled differences in local markets (such as coal and electricity prices), environmental regulations, water use restrictions, and product demand to be reflected in the assessment. In almost all cases, the expectations put forth in the Larson study were confirmed: typically, larger facilities that co-utilize coal and biomass exhibit economies of scale, allowing for lower cost production of liquid fuels, chemicals and electricity in addition to the traditional pulp and paper products. The study also found that capturing CO_2 and co-utilizing biomass as an energy feedstock help to offset the carbon intensity of the system, resulting in a transportation fuel and electricity product with a lower GHG intensity than their conventional counterparts.

In the biorefinery model, Larson et al. (2006) conducted a detailed assessment of lifecycle CO_2 emissions using the GREET model, which confirmed that reliance on biomass as the sole feedstock generates significant emissions reductions relative to conventional fuels production. In an energy park, however, which relies on coal as a key fuel source, CO_2 management becomes a serious design and cost issue. In some locations, petroleum coke or other opportunity fuels could supplement or displace coal as the fuel source, but, even so, management of carbon emissions still poses an important challenge. Therefore, reflecting the need to limit CO_2 emissions, the energy park design incorporates carbon capture and pressurization. We recognize that without a regulatory framework for long-term geologic storage, CCS is probably not a viable technology today. However we emphasize that, in concept, this configuration could be attractive. In addition, there are potentially enhanced oil recovery opportunities today that could provide markets for the CO_2 in a limited number of cases. In a similar vein to the "well-to-wheel" analysis of the biorefinery, Idaho National Laboratory (INL), also using the GREET model, examined a 50,000 bbl/day standalone synthetic fuel facility and found that a 70% coal/30% biomass feedstock split delivers a fuel with a carbon intensity equivalent to conventional petroleum.[3] Specifically, the INL study found that this biomass/coal feedstock mix without CCS produces synthetic diesel with GHG emissions almost identical to petroleum diesel; with CCS, at an 85% carbon capture rate, the plant generated synthetic diesel with 40% less GHG emissions than its conventional counterpart. Although a rigorous well-to-wheel analysis of the carbon balances associated with the energy park concept has not yet been conducted, the INL analysis suggests that the energy park configuration examined—using from 10-35% biomass, capturing 90% of carbon during production, and delivering high thermal efficiencies from the co-located P&P plant—would produce GHG emissions similar, if not lower, than those found in the INL study for synthetic energy products. The product costs also look attractive, mostly due to the ability to take advantage of energy and siting efficiencies. The economic results from the biorefinery and energy parks studies are summarized in the adjacent table and compared against national average prices as reported by the U.S. Energy Information Administration for context.

Product	Biorefinery	Energy Parks (with CO_2 Capture)	Conventional Fuels
Synthetic Crude Oil ($/bbl of oil equivalent)	51.00-82.00	43.00-57.00	94.77 November 2007 Monthly Average WTI Spot Price][4]
Power ($/MWh)	NA	38.00-57.00	57.00 [2006 EIA National Average Wholesale Electricity Price][5]

Comparative Prices of Energy Products

Because preliminary analysis of the energy park design directionally indicates that both liquid fuels and electricity can be produced with a lower carbon content than the conventional alternatives at attractive costs in the current market place without subsidies, we believe the concept deserves deeper exploration. Furthermore, the blend of coal and biomass examined in the initial energy parks study was one based on the current economics of markets for fuels and electricity. As synthetic fuel technologies evolve and as programs to regulate CO_2 materialize, presumably greater ratios of biomass to coal will become more economically viable, thereby improving the carbon footprint of this approach.

Conclusion

In an era of constrained energy supplies, increasing energy demand, and national energy security and environmental concerns, domestic resources that can meet our nation's vital energy needs in the liquid fuels and electricity markets—in a climate sensitive manner—deserve serious attention. P&P mills provide an attractive platform to integrate advanced gasification technologies to produce liquid fuels and electricity while managing CO_2 emissions. Though low volumes of liquid fuels can be produced cost-effectively using biomass alone at so-called biorefineries, energy parks, which co-utilize coal and biomass, provide an avenue to produce higher volumes of liquid fuels and significant quantities of electricity with GHG emissions lower than their conventional fuel-based counterparts. It should be emphasized that due to the number of P&P mills in the U.S., energy parks are essentially limited in their deployment potential and their ability to displace conventional petroleum. However, the energy parks design holds tremendous promise in providing a platform to test a system of technologies that could ultimately provide a pathway for large-scale, low-carbon synthetic fuel production in the U.S based on biomass feedstocks and CCS. Therefore, because energy parks could be cost-effective today without subsidies while effectively managing life-cycle CO_2 emissions, we believe they deserve strong consideration for further exploration, deeper analysis, and potential development.

Footnotes

[1] Larson et al. A Cost-Benefit Assessment of Gasification-Based Bio-refining in the Kraft Pulp and Paper Industry. December, 2006; Final report under DOE Contract DE-FC26-04NT42260

[2] Rezaiyan, A.J. et al. DOMESTIC ENERGY PARKS – FILLING THE TRANSPORTATION VOID. Energy and Environmental Research Center, University of North Dakota: May, 2007.

[3] Broardman, R. Plant Modeling and Emissions Comparative Analysis Approach Coal/Biomass Gasification with Fischer-Tropsch Diesel Production. Idaho National Laboratory: May 2007.

[4] Energy Information Administration

[5] ibid