Debris-Derived Biomass Pyrolysis to Produce Renewable Electric Power

Final Report

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Joseph Sayer
NYSERDA project manager

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Prepared by

Taylor Recycling Facility, LLC.
Montgomery, NY 12549
(845) 457-4021

Tom Kacandes, Project Manager

Co-sponsors:

Taylor Recycling Facility, LLC.

New York State Energy Research and Development Authority (NYSERDA)

FERCO Enterprises, Inc.

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ABSTRACT

This study performed an engineered cost estimate of a 300-dry ton per day SilvaGas Process gasifier using a mix of biomass and residual plastics derived from construction and demolition debris. The gasifier creates synthesis gas and steam used to power an electrical generating power island consisting of a boiler and steam turbine generator producing 11.5 megawatts net. The purpose was to determine the economic and environmental feasibility of a business model which receives mixed waste, then uses Taylor Recycling's processing technology to recycle inorganics (e.g. concrete, metals) and recyclable biomass (e.g. cardboard) and prepare a mix of unrecyclable biomass (plywood, varnish and creosote treated wood, textiles) and residual plastics (carpet, film) to feed the gasifier and power plant. The SilvaGas Process can maintain very low emissions using waste-derived fuel. It breaks down the biomass mix fuel in the absence of oxygen along with most treatments, plastics or laminates that could create problematic products of combustion in air-blown gasification or combustion technologies. The study concluded that such a plant built at Taylor Recycling's site in Montgomery, NY would be very desirable as an improvement over the present system of trucking waste long distance to landfills. The plant would provide base load renewable power, an advantage over intermittent sources such as wind. However, it would only be economically feasible under a narrow set of circumstances. Real and perceived risks that attach to this first commercial gasification plant greatly increased the range of estimated construction costs from best-to worst case and limit access to conventional financing.

Keywords: biomass, waste, recycling, gasification, renewable, air pollution

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SUMMARY

The purpose of this project was to determine the feasibility of producing renewable electricity from biomass derived from construction and demolition (C&D) debris. Taylor Recycling Facility is a national leader in sorting mixed waste and processing it into recyclable materials. Construction and demolition debris is about 30-35% of all solid waste. Recycling C&D debris as Taylor does is a small and fragile niche in the larger industry. More than 95% of such mixed debris is simply transferred from collection trucks to larger trucks that drive long distances to a dwindling number of "mega" landfills. Increasingly, the owner ship of these mega fills is concentrated in the top-10 waste disposal companies who control almost 90% of the business nationally. In the northeastern US, the clear trend is that more and more waste from New York, Massachusetts, Connecticut, and New Jersey is being exported to landfills in Ohio, Virginia, Pennsylvania, and even South Carolina. In 2003, this flood of waste exports rose to over 15 Million tons from these four states, and 8.3 Million tons from New York alone, making it the leading waste exporter in North America.

The air pollution and energy consumption implications of this accelerating trend are clear; we import more oil to run heavy trucks and repair roads, making the air we breathe dirtier just so we can send our garbage on vacation far away. New York is poorer as a result. Compounding this injury, once biomass waste is mixed with other waste and crushed into landfills, it begins to decay in a 30-year process that further pollutes the air with toxic hydrogen sulfide gas, large amounts of odorous methane gas and carbon dioxide, and even methyl mercury. No more than 40% of this total landfill air pollution is at least run through landfill gas to energy equipment to wring some minor benefit from this environmental disaster. The recent order by the New York State Public Service Commission (PSC) implementing a renewable portfolio standard directs the New York State Energy Research and Development Authority (NYSERDA) to collect money from ratepayers and pay a premium to "eligible" sources of renewable energy. Some of this environmental premium will go to support this system of landfilling biomass mixed with other waste, which releases to the air most of the methane gas, carbon dioxide and hydrogen sulfide it produces. To the extent some of these gases are captured to produce electricity, the equipment used can have the highest NOx (nitrogen oxides) and SOx (sulphur oxides) levels of any biomass system or "renewable" generation.

This report describes the detailed investigation of an alternative that is clearly superior from an environmental standpoint: Taylor Recycling now processes 250,000 tons per year of mixed waste to separate out recyclable materials (metals, concrete, cardboard, etc.) and converts the otherwise un-recyclable materials (insulation, shingles, debris fines, etc.) into a low-value soil substitute product at its two plants in Montgomery, New York and Des Moines, Iowa. Taylor can modify its waste processing

systems to shift the unrecyclable paper and boxes, textiles, plywood/glued wood and other "adulterated biomass" to a shredding process that also removes metal (e.g. nails) to create a biomass mix fuel that is converted to synthesis gas in the absence of oxygen in a new-technology gasification plant. This gas could then be burned in a standard gas boiler, producing steam to power a steam turbine that generates renewable electricity. The boiler and the gasification plant also generate hot flue gas. More steam to help power the turbine is produced as heat is removed from the inert flue gas prior to cleaning in best available pollution control equipment. This means waste stays in the local area that created it. Some of it is turned into recyclable materials and some into processed biomass that in turn becomes clean gas and then electricity to support the local grid. No gas escapes the process and the final emissions are minimal: less than 6 tons/year of nitrogen oxide (NOx) and one ton of particulate emissions with virtually no sulpur oxides (SOx), carbon monoxide or volatile organic compounds (VOC's). For each plant built in New York State, this "Recycling + biomass energy" system's small emissions would be offset many times by the avoided air pollution from long-haul trucking, and the massive green house gas (methane and CO2), SOx and hazardous air pollutant emissions from landfill disposal. It would also reduce energy use both from trucking and from recycling a steady stream of metals, aggregates, minerals and clean paper, boxes and textiles all missed by other recycling programs.

This system would convert 120,000 to 135,000 tons per year of biomass mix fuel (BMF) into 11.5 megawatts (MW) net electricity for sale through the grid. Under the initial premise of this study, this biomass fuel would be mostly plywood/particle board separated from mixed C&D debris with the rest being clean, unadulterated wood Taylor now recycles into mulch. We found this would not work economically, however, because there isn't enough plywood to feed a gasifier plant and it costs too much to stop recycling clean wood. In order to produce over 120,000 tons/year of biomass mix from mixed C&D debris, Taylor's New York plant would have to take in at least 357,000 tons/year of "raw" debris and recycle over 82,000 tons of metal, concrete, brick, drywall, and cardboard as well as 143,000 tons/year of soil substitute made from fines, treated/painted wood, insulation and shingles. Only 7.000 tons (2%) of the input 357,000 would still require landfill disposal.

Unfortunately, over 50,000 tons of clean wood that would normally be recycled would have to be turned into energy instead just to have enough fuel for this small size plant. This would turn a recycling revenue into a loss at a cost of more than $1 Million per year. In order to access the financial credits available under the Renewable Portfolio Standard (RPS), diversion of clean wood from recycling to energy seems to be required by the New York Public Service Commission's narrow definition of "eligible biomass" to mean only "wood". Diverting recyclable wood to energy production and subsidizing landfill gas produced from a mix that includes both unrecyclable and recyclable paper, textiles, food, wood, etc. is directly contrary to New York State's Solid Waste Management Act of 1988 which directs that New York agencies prioritize the recyclable fraction of each material go to recycling markets and the unrecyclable fraction go to energy as preferable to landfills, which are to be used only as a last resort. As of this writing, the PSC may yet clarify the biomass definition of eligible resources for the thermo-chemical "biogas" processes to include the "adulterated biomass" such as plastic contaminated unrecyclable paper, textiles, food and other biomass that are now eligible "biomass" only for landfills. This would do a great deal to make the "Recycling + Biomass Energy" system we studied economically feasible.

In conclusion, this study found:

- The system of "up-front" recycling and producing renewable electricity from gasification of the biomass mixes studied provides numerous environmental advantages and directly supports New York State solid waste policy by increasing post-curbside recycling and lowest-emission biomass energy and reducing landfill disposal.
- The gasification technology is clearly ready to be commercialized when coupled with a boiler / steam turbine based power island.
- Additional commercial scale verification of the gasifier process coupled to internal combustion gas engines, combustion turbines or fuel cells is required before there is commercial certainty on their use. All of these should prove to work well once the first commercial gasifier is built. Conceptual process flow diagrams for the engine and combustion turbine/combined cycle configurations including gas cleaning options were done as part of this analysis.
- More detailed conceptual work (including layouts, equipments lists, and a +/- 30% engineered cost estimate) was done for the gasifier and boiler/steam turbine which showed that the process should work well and produce low emissions, but that the cost of this option is relatively high per unit of electricity produced, and that the construction cost can vary widely depending on the construction methods used and labor cost assumptions.
- The gasifier incurs both higher capital cost than combustion technologies and significant operating costs in order to deliver three premium values:
    - lower emissions than fossil or biomass combustion
    - the ability to maintain those low emissions even when using non-wood biomass such as paper, textiles, or food that are contaminated by plastics, coatings or creosote and other treatments, and
    - the ability to run 24 hours a day with as little as two weeks downtime per year providing base load renewable power.
- Given New York construction and permitting costs, in cases where the gasifier / steam cycle power island has to purchase fuel (as other biomass or fossil generation do), biomass gasification is generally not price competitive even with wind power. To justify building such a plant to use purchased fuel, would require significantly higher electricity prices and a reduction in plant capital cost that should be possible in future plants that "learn" from the first few plants. This is especially true if using high cost, high moisture content energy crops.

- This study analyzed the use of biomass contaminated with plastics and non heavy-metal bearing coatings/treatments which could be received as mixed waste for moderate or standard disposal (aka "tip") fees of $35-$75/ton. The cost to separate other materials for recycling or disposal would have to be less than the tip fee in order to leave revenue to pay the gasifier to use the biomass mix fuel. Because this "first of its kind" gasifier must receive some revenue to offset its higher costs, the standard $/kilowatt capital cost estimate method does not provide an accurate comparison to other technologies that must buy their fuel.
- Because biomass is not very heavy (low density), and because the gasifier technology is not cost-effective at small sizes, the gasifier must draw its fuel from a small (45-65 mile radius) relatively populated area. In addition, construction debris and unadulterated wood provide a limited volume of cost-effective fuel in most areas of New York. It would be important to take advantage of the gasifier's ability to maintain low emissions using all available biomass from commercial waste, bulky waste (e.g. furniture) and non-C&D debris sources. Taking into account biomass from all waste sources, the area of the Hudson Valley, New York City, and Long Island have approximately 5-7 Million tons per year of biomass in its mixed waste streams. Landfills and waste incinerators are entrenched, often subsidized competition for this biomass, so the largest possible "pool" of energy-appropriate biomass is required to allow the gasifier to garner a share of the market without incurring unbearable levels of supply risk.
- Despite the several advantages of the Taylor Recycling site in Montgomery, NY (existing biomass processing and 69 Kv transmission line on site, high local power prices, Empire Zone tax advantages), the project as studied is not clearly profitable or able to be conventionally financed due to the high capital costs and "first project" uncertainties that come with the gasifier's premium values of low emissions, fuel flexibility, and base load renewable power.
    - Either the Renewable Portfolio Standard's definition of eligible biomass for thermo-chemical technologies must be expanded to include the full range of biomass the gasifier can process or the technology would have to be accepted as a new "waste-to-energy" technology that is an eligible resource to receive RPS premiums. With RPS support and the ability to be paid to accept its biomass mix fuel (just as RPS-eligible landfills are paid to accept mixed waste), the first gasifier could be built at Taylor Recycling's site which would allow construction cost savings and operating cost data to be developed to support future projects.
    - In addition, the first project could be built to allow a "side stream" of synthesis gas to be run through gas cleaning test equipment to provide commercially meaningful proof of it's suitability for use in gas engine generators, combustion turbines, and molten carbonate fuel cells at future plants. The use of the gasifier with these power islands could increase power output per biomass Btu input and lower emissions further, including the virtual elimination of even the possibility of dioxin/furan

emissions. It would also provide a truly renewable fuel source for fuel cells (in contrast to hydrogen reformed from natural gas as is now common).

- Finally, we examined the location of the gasifier near an existing boiler or power plant that could use synthesis gas as a topping fuel or substitute for coal, oil or natural gas. This would reduce the project cost to the gasifier only and generally would provide a net decrease in emissions from an existing source. This configuration could be advantageous at some point and in some cases, but introduces many complications to project development and represents a limited "market" of possible sites, at least until the first operating gasifier allows combustion turbine owners to be comfortable using biomass synthesis gas without requiring burdensome guarantees. It also introduces additional transportation costs for the prepared biomass mix fuel which would be made at a separately located recycling plant where it can receive mixed waste.